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# **THE FIRST JOINT REPORT**

of the  
**General Thomas P. Stafford Task Force**  
and the  
**Academician Vladimir F. Utkin**  
**Advisory Expert Council**



on  
**The "Shuttle-Mir" Rendezvous**  
and  
**Docking Missions**





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**AND THE ACADEMICIAN VLADIMIR F. UTKIN**  
**ADVISORY EXPERT COUNCIL**


**ON**

**THE "SHUTTLE-MIR" RENDEZVOUS**

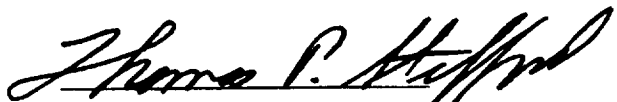
**AND**

**DOCKING MISSIONS**

Advisory Expert Council  
Chairman  
Academician Vladimir F. Utkin

  
Date 27 June 1996

Shuttle-Mir Task Force  
Chairman  
General Thomas P. Stafford

  
Date June 27, 1996

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# 1

## Introduction

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### 1.1 SHUTTLE-MIR MISSIONS - PHASE 1 OF THE INTERNATIONAL SPACE STATION PROGRAM

In October 1992, the National Aeronautics and Space Administration (NASA) and the Russian Space Agency (RSA) formally agreed to conduct a fundamentally new program of human cooperation in space.<sup>1</sup> The "Shuttle-Mir Program" encompassed combined astronaut-cosmonaut activities on the Shuttle, Soyuz Test Module (TM), and Mir station spacecraft. At that time, NASA and RSA limited the project to:

- ❑ the STS-60 Shuttle mission carrying the first Russian cosmonaut, Sergei Krikalev, to fly on the U.S. Space Shuttle,
- ❑ the launch of the first U.S. astronaut (Dr. Norman Thagard) on a Soyuz vehicle for a multi-month mission as a member of a Mir crew, and
- ❑ the change-out of the U.S.-Russian Mir crews with a Russian crew during a Shuttle rendezvous and docking mission with the Mir Station.

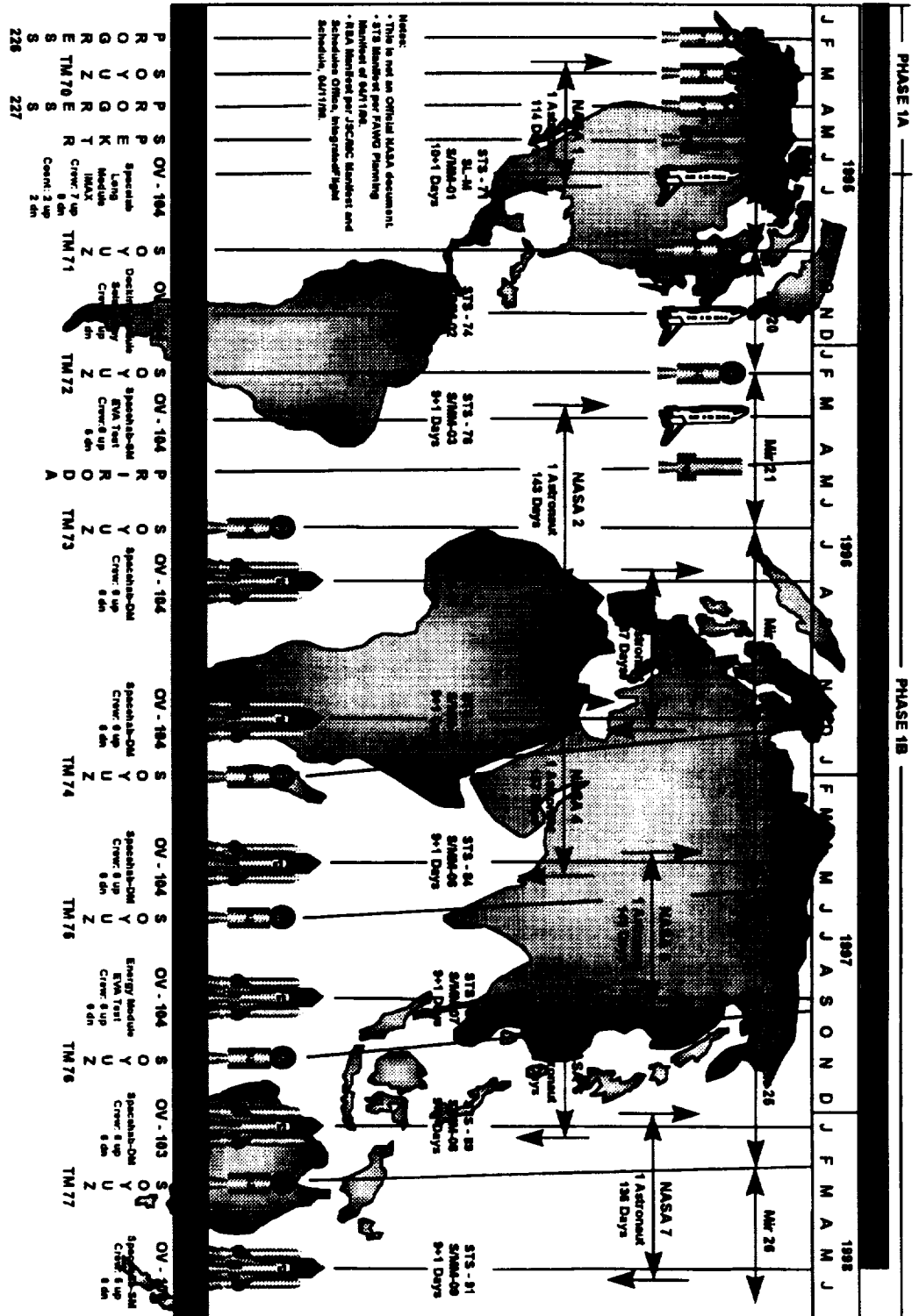
The objectives of the Phase 1 Program are to provide the basis for the resolution of engineering and technical problems related to the implementation of the ISS and future U.S.-Russian cooperation in space. This, combined with test data generated during the course of the Shuttle flights to the Mir station and extended joint activities between U.S. astronauts and Russian cosmonauts on board Mir, is expected to reduce the technical risks associated with the construction and operation of the ISS. Phase 1 will further enhance the ISS by combining space operations and joint space technology demonstrations. Phase 1 also provides early opportunities for extended U.S. scientific and research activities, prior to the utilization of the ISS.

In November and December 1993, NASA and RSA expanded the scope of the Shuttle-Mir Program considerably and made it Phase 1 of the International Space Station (ISS) program.<sup>2</sup> This expanded cooperation combined the original Shuttle-Mir Program with additional Shuttle flights to the Mir Station, including the STS-63/Mir-17 mission (Figure 1). Planned activity included further flights of U.S. crews aboard the Mir station allowing the combined U.S. astronaut experience in orbit on Mir to reach twenty-one months. Out of a total of ten possible Shuttle-Mir flights in

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1. "Implementing Agreement Between the National Aeronautics and Space Administration of the United States of America and the Russian Space Agency of the Russian Federation on Human Space Flight Cooperation," 5 October 1992.

2. "Addendum to Program Implementation Plan," 1 November 1993; "Protocol to the Implementing Agreement between the National Aeronautics and Space Administration of the United States of America and the Russian Space Agency of the Russian Federation on Human Space Flight of October 5, 1992," 16 December 1993.



Phase 1, NASA and RSA agreed to an initial baseline of seven Shuttle rendezvous and docking flights to *Mir*.

For the compensation of services that will be provided to NASA during Phase 1, NASA and RSA signed a \$400 million contractual agreement in June 1994. This contract enables NASA to purchase space hardware, data, and services from RSA and its subcontractors for approximately \$100 million per year through 1997 in support of the Phase 1 Shuttle-Mir missions and early ISS activities. Key elements of the contract include: (1) up to ten Shuttle-Mir dockings; (2) a combined total of 21 months of U.S. astronaut research on *Mir*; (3) three Extravehicular Activities (EVAs); (4) transport of 7,716 pounds (3,507 kilograms) of dry logistics and of water respectively to the *Mir*; (5) operation of 5,070 pounds (2,305 kilograms) of NASA hardware on *Mir*; (6) a Russian developed docking mechanism for use on the Shuttle during the docking with *Mir*; (7) a Russian developed Docking Module (DM) for Shuttle use with *Mir*; and (8) up to \$20 million to support Russian scientists engaged in ISS scientific and research programs.<sup>3</sup>

In January 1996, the scope of U.S.-Russian cooperation was expanded for a third time. Responding to Russia's desire to maintain the operability of the *Mir* station through 1998, the NASA Administrator, Mr. Daniel Goldin, and RSA General Director, Mr. Yuri Koptev, agreed to extend the Phase 1 activities through 1998, and increase the manifested number of Shuttle flights to the *Mir* station from seven to nine.<sup>4</sup> Although still under review, this change to Phase 1 (known as Phase 1C) would replace the Solar Dynamics payload on STS-86 with additional logistics for

the *Mir* station, would add a Shuttle-Mir flight to the Shuttle manifest (STS-89) and would redirect the STS-91 mission to rendezvous and dock with the *Mir*.

In preparation for the construction of the ISS, the Shuttle program is gaining necessary experience in rendezvous and docking with large structures and in logistics transfer. The Shuttle is participating in crew and cargo delivery to the *Mir*, under the Phase 1 agreements between NASA and Russia. For example, the Shuttle is bringing new solar arrays to replace existing arrays on the *Mir*. *Mir* capabilities are being enhanced by U.S. and Russian contributions of hardware and software.

Under contract, the Rocket Space Corporation-Energia (RSC-E) supplied a docking mechanism used on STS-71, the Androgynous Peripheral Docking System (APDS). The APDS is a modification of the three-petaled, androgynous design used on the Apollo-Soyuz Test Project mission of July 1975 (Figure 2). It is being used on the Shuttle Orbiter Docking System (ODS) and on a DM developed by RSC-E. After being permanently attached to the *Mir* on the STS-74 mission, the DM facilitates future docking missions by eliminating the need to move Kristall. The use of the DM also extends the life of the Kristall manipulator arm.

Between April and August, 1995, three Progress flights delivered 623 pounds (283 kilograms) of mostly life science hardware for NASA experiments to be conducted on *Mir*. In 1995 and 1996, Russia added two modules (*Spektr* and *Priroda*) to the *Mir* equipped with 3,430 pounds (1,559 kilograms) of U.S. and Russian scientific hardware to support long-duration life and

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3. Contract NAS15-10110 between the National Aeronautics and Space Administration of the United States of America and the Russian Space Agency of the Russian Federation for Supplies and Services Relating to *Mir*-1 and the International Space Station: Phase One and Selected Phase Two Activities, 23 June 1994.

4. "NASA-RSA Human Space Flight Cooperation Principles and Action Plan," 26 January 1996.

microgravity science and research experiments aboard *Mir*.

While the program is only at its half-way mark, Phase 1 is achieving many of the objectives it was designed to accomplish. NASA and RSA have successfully completed one close Shuttle approach to within 33 feet (10 meters) of *Mir* (STS-63) and three Shuttle-Mir docking missions (STS-71, STS-74, and STS-76). Russian cosmonauts have participated in three Shuttle missions: STS-60, STS-63 and STS-71. A U.S. astronaut participated in the 115 day *Mir*-18 mission. Twenty-one months of U.S. astronaut presence aboard *Mir* is underway with a second U.S. astronaut currently conducting research on the Russian station. Data from the loads generated when docking the Shuttle to the *Mir* is being used to assist ISS planners and structural engineers.

Although each Shuttle-Mir mission to date has presented issues to consider jointly, both sides have done a commendable job in overcoming significant cultural and technical differences to resolve difficult programmatic and technical issues. Generally, lessons learned from each mission are being effectively used to improve processes and future collaboration. Most importantly, the U.S. and the Russian space programs are achieving the kind of interoperability experience through the Phase 1 missions necessary to construct the ISS on schedule and within budget.

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## 1.2 THE TASK FORCE AND THE ADVISORY EXPERT COUNCIL

In May 1994, the NASA Advisory Council established the Task Force on the Shuttle-Mir Rendezvous and Docking Missions with Lieutenant General Thomas P. Stafford, USAF (retired) as its chairman.<sup>5</sup> The purpose of the Task Force is to review Phase 1 planning, training, operations, rendezvous and docking, and management.<sup>6</sup> The Task Force provides interim reports containing specific recommendations to the NASA Advisory Council (NAC), which reviews and approves the recommendations before sending them to the NASA Administrator.

Between June and November 1994, the Task Force presented three reports to the chairman of the NAC, Dr. Bradford Parkinson. The reports contained recommendations on a number of issues including management of the program, timing for crew selection and training, and Shuttle-Mir rendezvous and docking flight operations.

On December 6, 1994, in conjunction with the expansion of U.S.-Russian cooperation in space and the incorporation of the RSA in the ISS Program, NASA Administrator Goldin directed General Stafford as the chairman of the Task Force, to coordinate efforts with a similar Russian

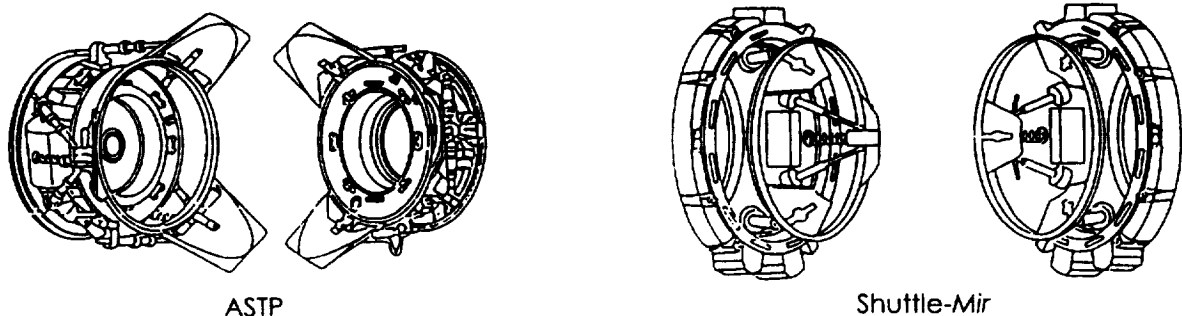


Figure 2 — ASTP and Shuttle-Mir docking mechanisms

review group and review preparations and readiness of upcoming Shuttle-Mir flights under the ISS Phase 1 Program. General Stafford organized a review team to focus on the Soyuz TM-21 flight with an international crew of Russian cosmonauts Vladimir Dezhnev, Gennady Strekalov and U.S. astronaut Norman Thagard, the three month Mir-18 mission on which they flew, and the Shuttle mission on which they returned.

In conjunction with this action, Russian Prime Minister Victor Chernomyrdin, and U.S. Vice President Al Gore, directed the RSA General Director and the NASA Administrator to establish a process to review each other's program plans and capabilities and to report periodically to the GCC.<sup>7</sup> In response to this direction, Mr. Koptev and Mr. Goldin agreed to form a joint committee. This committee, headed by Academician Vladimir F. Utkin, Director of the Central Institute for Machine Building (TsNIIMash), and General Stafford, was charged to provide joint reports to the RSA General Director and the NASA Administrator.

RSA General Director Koptev appointed Academician Utkin to chair the Advisory Expert Council on Mir station and Shuttle Vehicle Joint Flight Support Problems and formally approved its membership on February 14, 1995.<sup>8</sup> The Advisory Expert Council was instructed to provide independent assessments of the state of affairs, elaboration of recommendations, and additional measures, if necessary, of the level of reliability, safety, crew training, and efficiency of the planned program associated with the joint Russian-U.S. missions to Mr. Koptev.<sup>9</sup>

In January 1995, the review team, headed by Major General Joe Engle, USAF (retired), arrived in Moscow to acquaint themselves with the RSA and other Russian organizations supporting the Phase 1 missions. The delegation visited RSA, the Central Research Institute for Machine Building (TsNIIMash), the Mission Control Center-Moscow (MCC-M), RSC-E, the Khrunichev State Research and Production Space Center, the Gagarin Cosmonaut Training Center (GCTC), and the Baykonur Cosmodrome. The team prepared a report with recommendations and presented them to General Stafford who then returned with the team in February 1995.

Upon return to the United States, the Task Force compiled their observations and recommendations into a fourth report and briefed the NAC and Mr. Goldin. The Task Force found that based on data review, interviews, discussions, and site visits conducted by the review team in the United States and in Russia, the Phase 1A missions (Soyuz TM-21, Mir-18, and STS-71) faced no unacceptable risks. The report stated that, "At the core of the finding is the conclusion that the interface between the U.S. and Russian civil space organizations is operating effectively and that the processes, hardware, and people necessary to safely complete the Phase 1A missions are in place."<sup>10</sup>

A third meeting was held in March in Russia between General Engle and Mr. William Saxe, the NASA Representative in Russia, and Academician Utkin. Academician Utkin and members of the Advisory Expert Council visited the Lyndon B. Johnson Space Center (JSC) in Texas, the

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5. See Attachment 1 for a list of the Task Force members and technical advisors.

6. See Attachment 3 for a complete copy of the Task Force charter.

7. December 15, 1994, meeting of the Gore-Chernomyrdin Commission (GCC) Space Committee.

8. See Attachment 2 for a list of Advisory Expert Council members.

9. See Attachment 4 for a complete copy of the Advisory Expert Council charter.

10. "Fourth Report: Task Force on the Shuttle-Mir Rendezvous and Docking Missions," 1 March 1995.

## *First Joint Stafford-Utkin Report: Shuttle-Mir Rendezvous and Docking Missions*

John F. Kennedy Space Center (KSC) in Florida, the George C. Marshall Space Flight Center (MSFC) and Boeing in Alabama, and NASA Headquarters in Washington, D. C. between March 31 and April 10, 1995. During this visit, the two review groups discussed issues related to the joint STS-71 flight. The Advisory Expert Council included these discussions in its report which it presented to RSA General Director Koptev in June 1995.<sup>11</sup>

The Advisory Expert Council concluded that "the level of interaction of all Shuttle elements, the experience accumulated during previous missions and staff qualifications eliminate the grounds for concern and provide confidence in a successful STS-71 launch."<sup>12</sup> This conclusion was based on 67 successful Shuttle launches prior to STS-71, productive interaction between the personnel in the mission control centers in Moscow and Houston, 26 manual dockings in space, high

crew qualification and the successful completion of the STS-63 mission in February 1995, when the Shuttle rendezvoused with the *Mir* to a distance of 33 feet (10 meters). The Advisory Expert Council report identified several technical and medical issues as well.

Both the Task Force and the Advisory Expert Council's report conclusions were confirmed by the successful flight of STS-71 and its joint docked operations with the *Mir*. Furthermore, preparations for these separate, independent reports and conclusions provided the foundation for a close working relationship between the Task Force and the Advisory Expert Council. Another key ingredient in the successful relationship between the two review groups was the tremendous support that they received from the U.S. and Russian personnel in the Phase 1 and Phase 2 programs.

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11. "The Advisory Expert Council's Report on the Problems Related to the Joint *Mir*-Shuttle STS-71 Flight," June 7, 1995.

12. *Ibid.*

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### **1.3 FIRST JOINT MEETING OF THE TASK FORCE AND THE ADVISORY EXPERT COUNCIL**

The success of the first joint Task Force-Advisory Expert Council meeting in September 1995, stemmed from this history of cooperation and collaboration between the Task Force and the Advisory Expert Council members, which in turn has been significantly aided by the Phase 1 and Phase 2 program offices. The review bodies quickly reached agreement on the basic objectives of the joint activity. These objectives were incorporated into a joint charter, and a schedule of joint activities and joint reports was established.<sup>13</sup>

A preliminary draft of the report was developed and submitted by the Advisory Expert Council in November 1995. The Task Force

reviewed and revised the draft, and returned it to the Advisory Expert Council in March 1996. In April 1996, General Engle led a small delegation to Russia to participate in an international conference in commemoration of the 50th anniversary of the founding of TsNIIMash. During this visit, the status of the Joint Report was reviewed. A second draft containing many of the revisions discussed in Russia was provided by the Task Force to the Advisory Expert Council in May 1996. This report was finalized in June.

Considerable effort has been invested in obtaining the data and performing the analysis necessary to produce this joint report during numerous meetings and teleconferences between the September 1995, meeting in Moscow and the July 1996, signing in Houston, Texas. The consistent openness and support of the Phase 1 and 2 Program offices has been essential throughout this process.

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13. See Attachment 5 — Charter of the Shuttle-Mir Task Force and the Advisory Expert Council.





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# 2

## Joint Report Objectives

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The objective of this report is to combine the independent expertise of the Task Force and the Advisory Expert Council in jointly identifying and analyzing issues regarding the preparation and implementation of the Phase 1 program. The observations and opinions expressed in this report have been jointly developed. Any recommendations which are developed as a result of this report should endeavor to reduce technical risk associated with implementing the Phase 1 program. Any recommendations will be submitted in separate documents by General Stafford to NASA Administrator, Mr. Daniel Goldin through the NAC, and by Academician Utkin to RSA General Director, Mr. Yuri Koptev.



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# 3

## Issues and Resolutions

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### 3.1 PLANNING

#### 3.1.1 Electromagnetic radiation arising from Ku-band antennae operation

As reflected in the STS-71 Flight Rules, the level of electromagnetic radiation of the Shuttle Ku-band antenna at full power exceeds the permissible level of electromagnetic influence on some of the structural elements and equipment of the *Mir* station. Based on data and analysis of the STS-63, STS-71, and STS-74 flights, timeline schedules of the Ku-band antennae operations and corresponding power output transmissions of the *Mir* antennae were examined. It was determined that restrictions and limitations were required and should be established.

#### Resolution

The Shuttle Ku-band system operates under established procedures which provide dual redundant protection for both radar and communications functions. Power is automatically switched to low power at radar lock-on and is backed up by manual switches. In the communications mode, automatic masking protects all *Mir* modules. The *Mir* Ku-band antennae are turned off once the Shuttle approaches to within 100 feet (30.5 meters).

#### 3.1.2 Untended *Mir* operations

Prior to the STS-71 undock and fly away maneuver, the crew of *Mir-19* boarded the Soyuz TM-21, undocked from the *Mir*, and maneuvered to a position 305 to 366 feet (93 to 112 meters) away to photograph the undocking of *Mir* and *Atlantis*. During these proceedings an inadvertent command was sent from MCC-M, which resulted in the *Mir* loss of attitude control and its going to free drift. The *Mir-19* crew displayed superb piloting skills by executing an immediate return and manual docking maneuver. Under established flight rules, the Shuttle will not dock with the *Mir* in free drift. If the Soyuz crew had been unable to perform the docking, they would have had to return to Earth and the *Mir* would have been untended for an unplanned, extended duration. Considering the crew activity required to maintain *Mir* systems, this could have jeopardized or even resulted in possible loss of the *Mir* and termination of the Phase 1 Program.

#### Resolution

Both NASA and RSA agreed to continue to evaluate and consider the safety of conducting external photography of the Station and performance of this activity only during opportunities such as *Mir* crew rotation. Meanwhile, NASA's Phase 1 Program management continues to stress the risks inherent in such operations and to request that untended operations be conducted

only when necessary to conduct essential repairs or maintenance on the *Mir*.

### **3.1.3 *Mir* re-certification and projected life**

The Union of Soviet Socialist Republics (USSR) developed and launched the *Mir* orbital station in February 1986. The original life resource of the station was three years with the expectation that it would be extended to five years.

RSC-E extended and re-certified *Mir* station operations by: (1) control of design parameters of on-board systems; (2) annual system re-certification, within safety perimeters, until system shut-down or replacement due to resource (such as the second collector of the main thruster, external hydropumps, and the thermo-regulation system) exhaustion; (3) control of internal and external influences having an immediate impact on safety (including radiation, the consistency of the station's atmosphere, toxicity, fire, orbital debris, damage due to external contamination); (4) comprehensive maintenance operations on systems using consumable resources; (5) developing methods for conducting of complex maintenance-repair operations; and, (7) conducting advance tests of material resources, devices and aggregates, critical from the point of view of safety and reliability during operations. In addition, based on long-term planning, RSA certifies the *Mir* for each joint mission with Shuttle and issues recommendations where appropriate.

In accordance with the terms and conditions of the NAS15-10110 contract, NASA receives quarterly reports on the implemented activities and the status of the design parameters of on-board systems, modules and on the *Mir* station as a whole. NASA takes part in the activities for extension the *Mir* life resources. This participation had not been anticipated, but arose as the result

of broader opportunities for using the Shuttle to return various on-board hardware to earth.

Just prior to the tenth anniversary of the *Mir*, the RSA notified NASA of its intention to maintain the *Mir* station through 1998. Discussions were held at JSC where NASA and RSA officials agreed to extend the operational life of the *Mir* and re-supply it with additional Phase 1 Shuttle rendezvous and docking flights.

In agreeing to extend the lifetime of the *Mir* resources for the support of work under Phase 1, RSA had to conduct the following activities: (1) additional structural verification tests related to increased payload requirements and frequent Shuttle docking; (2) main system (such as electrical, life support, and thermo-regulation) design parameter improvements to extend the duration and improve the fidelity of operations, especially in relation to increased crew requirements; and, (3) instrumental module modifications and usage of motion control systems for Shuttle-*Mir* docking and joint operations.

Russia's space organizations successfully completed these activities due to accumulated technical experience regarding *Mir* systems and extended the *Mir* lifetime to perform the work under Phase 1. NASA was given an opportunity to study the unique experience of long term operations of a permanently-manned orbital station to be used for ISS development.

### **3.1.4 Space Shuttle re-certification**

The Space Shuttle Program follows the basic policy that all flight hardware, software and safety critical ground support equipment and software needs are to be certified by the program and project managers of both NASA and the contractor prior to each Shuttle flight. This process is known as Certification of Flight Readiness (CoFR). During CoFR development, each project element responsible for hardware (or software) conducts

an Acceptance Review of the hardware and its supporting documentation.

### 3.1.5 Space Shuttle projected life

The Space Shuttle orbiters were designed for a 10-year service life, which has been extended to 20 years, based upon additional testing and 100 missions per vehicle. Orbiter flight certification was increased from 20 missions to 100 missions in mid-1995, due to improvements in the theory used to analyze load data. There are approximately 1,000 orbiter parts per flow that are designated limited life. These parts are continuously reassessed due to changes in or better information on loading profiles. There are 23 "fracture critical" limited life parts that do not meet the 100 mission life profile of most of the Space Shuttle. As NASA gains better understanding, predictive models are improved, providing greater accuracy.

The Space Shuttle Main Engines (SSMEs) were initially designed with a 50 mission life goal

(Figure 3). Currently the engines fall far short of this goal due primarily to required inspections. There is a requirement for all parts to be inspected at certain times for indications of impending failure. All components must be within their allowed lifetime and must be inspected as required prior to flight certification.

The Solid Rocket Booster (SRB) Assembly was designed for a twenty mission life (Figure 3). SRBs are certified to meet all specified reuse dimensional requirements, acceptance test criteria, and performance requirements before being certified as ready to launch. The rebuilt SRBs are considered to be "as good as, or better than, new." Upon passing their acceptance tests they are analytically capable of performing a minimum of four additional launches (even though they still have to pass the test each time they fly).

Like the SRBs, the Reusable Solid Rocket Motors (RSRMs) are certified to meet all specified reuse dimensional requirements, acceptance test criteria, and performance requirements

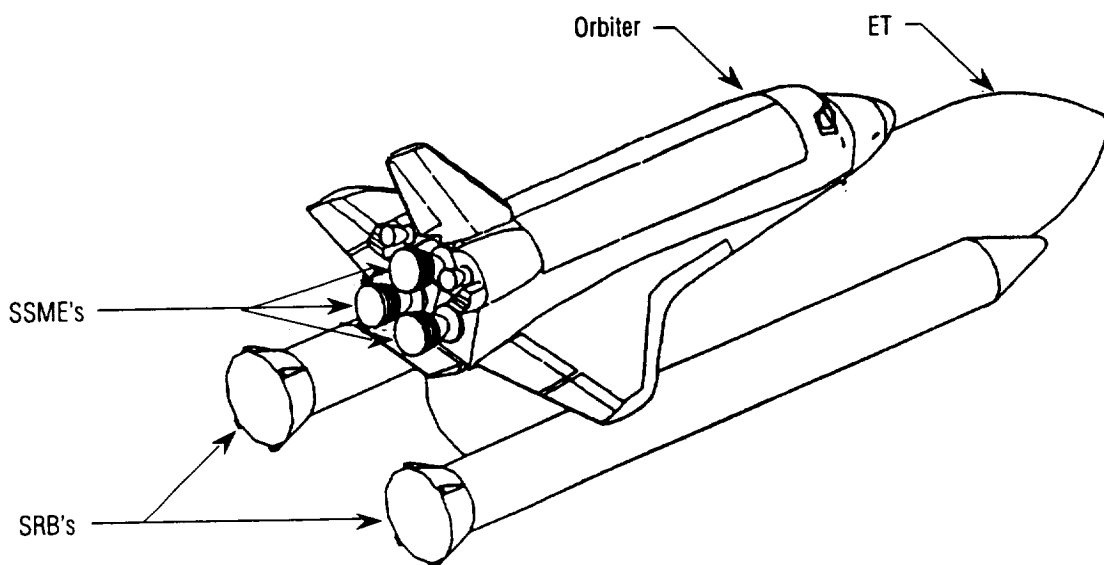


Figure 3 — Space Shuttle major components.

before being certified as ready to launch. The rebuilt RSRMs are considered to be "as good as, or better than, new." Upon passing their acceptance tests, they are analytically capable of performing a minimum of seven additional launches (RSRMs have to pass the proof tests each time they fly).

The External Tank is an expendable hardware item designed for one use only (Figure 3).

The launch processing efforts, personnel, training, equipment, hardware, software and facilities at KSC are reviewed at element level reviews and certified by both the Shuttle Processing Contractor and NASA-KSC.

RSA is invited to participate in the Flight Readiness Reviews for Shuttle-Mir docking missions, which occur approximately three weeks prior to the launch.

### **3.1.6 Protection of crews from depressurization during launch/entry**

In discussions regarding Russian cosmonaut safety aboard the Space Shuttles STS-60, STS-63 and STS-71, concerns were raised relevant to the current level of protection provided by the Launch and Entry Suits worn by Shuttle crew members. With the probability of the Space Shuttle being considered as a crew transfer vehicle for multi-national crews during phases 2 and 3 of the ISS, consideration of this subject may again be appropriate.

#### **Resolution**

Currently there are two types of suits worn during launch and entry, the Launch and Entry Suit (LES) and the Advanced Crew Escape System-LES (ACES-LES). The LES is being replaced by the ACES-LES, but both are designed to facilitate quick and safe egress/escape in an emergency occurring pre-launch, in flight, or post-landing, and to protect crew members from the following:

- ❑ Loss of cabin pressure
- ❑ Environmental extremes
- ❑ Effects of prolonged gravity
- ❑ Contaminated atmosphere

The LES is a partial pressure suit with mechanical pressure exerted by pressure bladders that cover most, but not all of the body. The ACES-LES is a full pressure suit that covers the entire body. ACES-LES suits are being acquired at the rate of approximately one per month. With the current procurement/delivery schedule, adequate numbers and sizes of these suits should be available to accommodate all Space Shuttle crews by the end of calendar year 1997.

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## **3.2 TRAINING**

### **3.2.1 Complete payload Flight Data File not available for training prior to flight**

Russian to English translation of the Payload Flight Data File (FDF) has not been provided to the crew in time for desired training. This impacts both training and mission operations. In the sequence of procedure development the Russian "curator" review occurs after the procedures are defined. As a result, their comments are incorporated and translated no earlier than for the final FDF, which is long after training has commenced. Although the FDF is supposed to be finalized at approximately three months prior to end of training, the final FDF is typically not available until just prior to launch. The curator procedure review needs to come earlier, at least during the procedure verification process that occurs before training, and translated documents need to be available in Russian and English for the crew.

## **Resolution**

NASA reached agreement with RSA and RSC-Energia to address this issue. Under this agreement, RSA curators review FDF procedures and operations manuals for safety and compatibility with Mir, prior to establishing the procedures in English and in Shuttle format. This essentially moves the procedure review by the curators to immediately prior to the procedure verification time frame. The procedures are translated into Russian for use by the cosmonauts and placed into a book with the English version on the left and the Russian version on the right.

### **3.2.2 Reduced Soyuz TM space vehicle training time for U.S. Mir crew members**

Training time for joint missions is extremely demanding on the assigned crew's availability. If the role of the U.S. crew members while on the Soyuz vehicle is to be limited to emergency undocking and entry functions only, the level of training conducted at the GCTC may well be reduced to a level of proficiency compatible with these requirements.

## **Resolution**

Soyuz training for U.S. crew members has been reduced to the minimum required for rescue vehicle purposes. NASA and RSA may further evaluate this level of training based on both trainer and crew comments. Additionally, in the interest of optimizing time and resources NASA is considering the provision of a Soyuz trainer at JSC. A JSC-based Soyuz trainer would furnish familiarization, training, and proficiency for NASA astronauts and appropriate Mission Control Center-Houston (MCC-H) personnel. This JSC-located trainer would not eliminate the training at the GCTC by their expert training instructors,

but could provide initial familiarization for selected crews resulting in more efficient and cost effective training. In addition, it would provide proficiency sessions following GCTC departure for the Shuttle launch to Mir, thus enhancing safety in the event of an emergency return.

### **3.2.3 Restriction of physical conditioning equipment use during mated flight**

During docking and joint activities between Mir and STS-74, numerous restrictions in the use of treadmills, rowing machines or other exercise devices have been imposed. Such restrictions on the use of the "veloergometer" (ergometer) and the treadmill can have a negative impact on the physical conditioning of the cosmonauts.

## **Resolution**

Medical experts from both sides agree that these restrictions may result in significant decrease of physical conditioning of the Mir crews. Consideration is being given to coordination between structures and operations experts in developing alternative exercise equipment and opportunities. The operations community recognizes this concern and has determined that only one treadmill should be used at a time and no Shuttle Primary Reaction Control System (PRCS) jets should be used while the Shuttle is docked to Mir.

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## **3.3 OPERATIONS**

### **3.3.1 U.S. crew members on Mir**

During Mir-18, astronaut Dr. Norman Thagard noted that communication with his family was limited and needed to be expanded. Also, it was

observed that, due to the make-up of the crew, communications onboard *Mir* were restricted to exclusively the Russian language.

### **Resolution**

To minimize feelings of isolation among the U.S. crew aboard the *Mir* Station, a joint agreement was implemented for an overall communication plan that ensures that U.S. crew members are provided with dedicated air to ground time for both personal and mission related communications. It appears that this plan is working adequately based on comments from the second NASA cosmonaut-researcher currently on-board *Mir*.

### **3.3.2 Restoration of the temperature and humidity environment on *Mir***

From April to November 1995, an unfavorable situation occurred on-board the *Mir* station with the environment's temperature-humidity regime. Although the temperature and humidity of the station environment, in general, was in the allowable range, it became a source of discomfort for the crew. The situation was caused by the following:

- ❑ calibration of a new on-board air conditioning system water separator required more time than had been expected because of its numerous flaws;
- ❑ limited electrical power on the *Mir* station did not allow for necessary operation of the on-board thermal/humidity control system module;
- ❑ unfavorable attitude of the station which did not allow for all the modules' lateral surface to be periodically exposed to the Sun; and,
- ❑ structural thermo-stationary peculiarities (solar energy absorption) of the Kristall and Spektr modules' bodies.

### **Resolution**

The following measures were implemented to remedy the situation on the station:

- ❑ additional measures for the improvement of the temperature-humidity regime of the pressurized compartment on *Mir* with the help of the cooling and dehumidifying system on Soyuz-TM and the life support system on the Shuttle;
- ❑ test activation and calibration of the on-board air conditioning system, ACU-3;
- ❑ collection and removal of accumulated condensation; and
- ❑ monitoring of the free condensation inside pressurized compartment of the *Mir* station.

Reports from the crew of *Mir-20* indicated comfortable temperature and humidity with regards to the *Mir* environment.

### **3.3.3 Emergency de-orbit during Shuttle EVA operations**

Concerns were raised regarding NASA standards for evacuating U.S. EVA astronauts in an emergency Shuttle deorbit contingency situation when the Shuttle is docked to the *Mir* Station.

### **Resolution**

Current NASA timelines for an emergency de-orbit require that payload doors close within 20 minutes after discovery of the emergency problem. In such an emergency, U.S. EVA crew members would terminate their EVA tasks and immediately return to the Shuttle payload bay. The crew would commence the undock and separation maneuver and payload bay door closure would begin. U.S. EVA crew ingress into the Shuttle airlock could occur simultaneously with, or subsequent to, the undock and payload bay door closing operations. Life sup-



port limitations for additional crew members aboard *Mir* are recognized. There is no intention of abandoning U.S. EVA crew members at the *Mir* station in the event of an emergency requiring immediate Shuttle de-orbit.

## 3.4 RENDEZVOUS AND DOCKING

### 3.4.1 Shuttle-Mir approach profile

Prior to the STS-63/*Mir*-17 Rendezvous mission, concerns were expressed by both the RSA and NASA regarding the loads and contamination effects of the Shuttle Reaction Control System (RCS) during approach and docking with the *Mir* Station. Of particular concern were the structural and dynamic loads on specific *Mir* solar panels, and the effects of accumulated propellant residue on solar panels and the Soyuz Infra-red (IR) horizon sensor used for re-entry.

#### Resolution

In addition to employing the Low-Z RCS thruster configuration (Figure 4) from 1,000 feet (305 meters) to within 30 feet (9.1 meters) range, the

Velocity Vector (V-bar) approach (Figure 5) used on STS-63 was replaced with the Radius Vector (R-bar) approach for STS-71 and subsequent Shuttle missions to *Mir*. By taking advantage of the orbital mechanics of this type approach, up-firing RCS jets used for braking and their adverse plume effects on the *Mir* were minimized.

### 3.4.2 Shuttle-Mir docking loads analysis and methodology

Prediction of off-nominal or maximum docking loads to be expected during the Shuttle-Mir Phase 1 missions is challenging and is not an exact science. For example, over 600 closed loop simulator runs, including selected systems failures and off-nominal initial conditions, have resulted in a three sigma maximum lateral velocity of about 0.4 inches per second (1 cm/sec). The projected limitations, based on APDS capability, are 1.8 inches per second (4.6 cm/sec), providing an apparently large margin which has not been explored for loads analysis. It is critical to select a method and technique which will assure that the lifetime structural design limits of *Mir* are not exceeded. It is also necessary to select a methodology which considers reasonable bonds of cost, schedule, risk and operational impact.

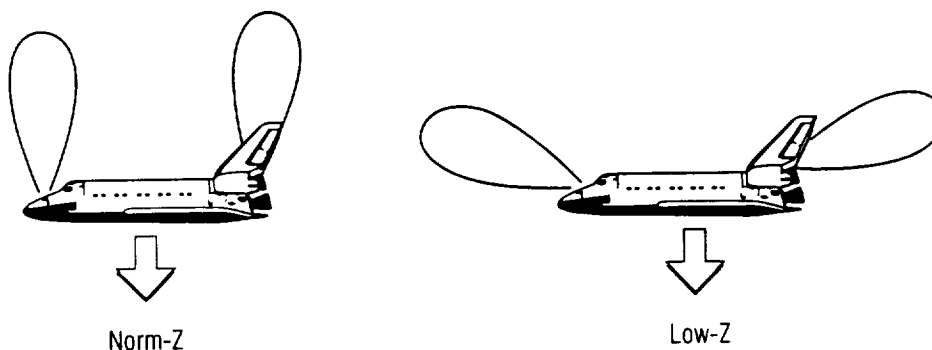


Figure 4 — Braking maneuver showing Norm-Z and Low-Z.

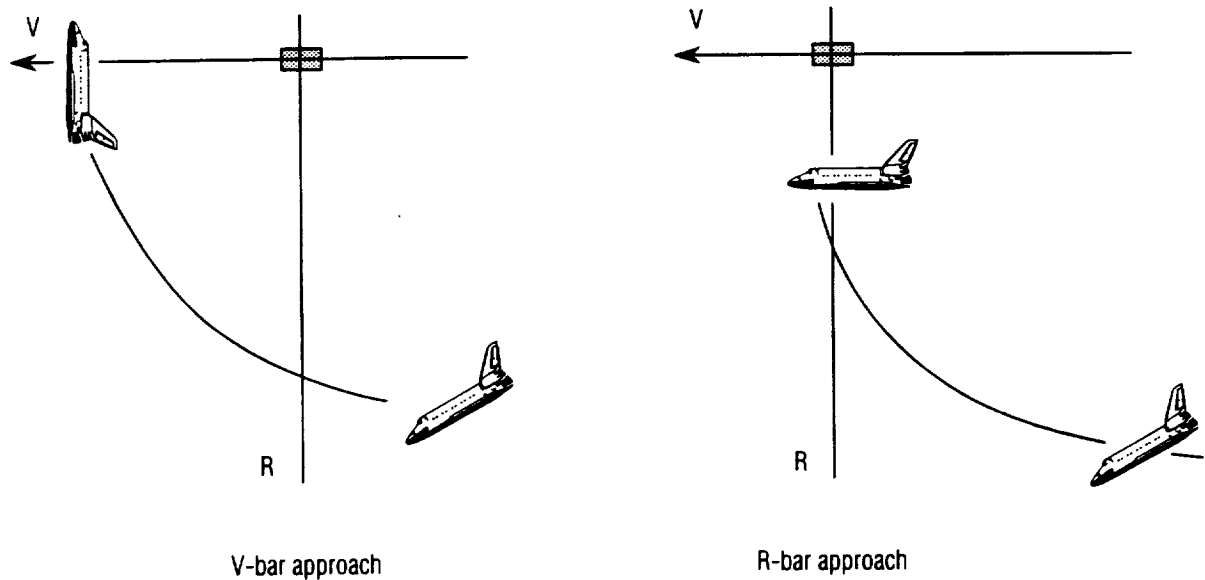


Figure 5 — V-bar and R-bar approaches.

## Resolution

To assume absolute worst case loads using limiting values for all contact conditions simultaneously, while highly improbable, would be unreasonably conservative. Although statistical techniques are less conservative and have fewer historical precedents than "worst on worst" techniques, they were chosen for the docking loads discipline with full knowledge that the structures involved had a mature design and operational history. The solution methodology was backed by confidence in the structures involved, simulation accuracy/ results, and crew performance in training and database runs. Based on crew simulator and flight performance, statistical techniques also assume the limits will not all occur simultaneously when docking to *Mir*. As the number of flights increases, the statistical significance of the flight reconstruction and comparisons to statistical design limits adds even more confidence in the

selected statistical methodology. However, NASA recognizes that augmenting the statistics to include the additional planned docking missions to *Mir* must be implemented.

### 3.4.3 Shuttle plume effects on *Mir* structural elements

Loads imposed by the Shuttle PRCS jets on the structural elements of the *Mir* station during docking have been studied and the results documented from flights STS-63, STS-71, STS-74, and STS-76. As the *Mir* station configuration changes, it is prudent to continue to perform analyses to verify that loads on all *Mir* elements are not exceeded.

## Resolution

Load patterns from RCS plumes have been measured using the Shuttle Plume Impingement Flight Experiment (SPIFEX) device on the STS-64. Confidence has been gained in the plume

model and plume analysis techniques by observing *Mir* solar panel responses during the close proximity operations of STS-71, STS-74 and STS-76. This knowledge will be applied to changes in the *Mir* configuration as they occur.

#### 3.4.4 Leaks from RCS thrusters during STS-63

Prior to STS-63, several missions recorded oxidizer leaks from the Shuttle RCS. There were no safety of flight concerns related to these leaks, and prior to STS-63 they did not threaten mission success. In the proximity of the *Mir*, however, propellant leaks pose significant risks for damage to the critical sensors and power collecting solar arrays of the Soyuz return vehicles and the *Mir*. Although both U.S. and Russian teams worked together in a timely manner to develop and agree on a solution during the STS-63 mission, it is prudent to continue to study the problem of leaking RCS jets in order to prevent re-occurrence of an RCS leak during a Shuttle-*Mir* docking mission. The RCS jet leak on the STS-77 mission confirms that it is also prudent to expand contingency procedures for leakage situations occurring before rendezvous and while the Shuttle and the *Mir* are docked.

#### Resolution

The cause of the Shuttle RCS leaks in the oxidizer Pilot Operated Valves (POVs) was the accumulation of metallic nitrate contamination in the areas of the seals. Changes have been implemented to increase the reliability of the RCS primary thrusters. These changes fall into three broad categories: (1) **operations improvements**, which consist of emphasizing the maintenance of the RCS propellant system in a hard filled (wetted) state, improved thermal conditioning, and reduction of moisture intrusion into the system; (2) **improved valve maintenance**, which

is obtained by required periodic thruster flushing of all jets in the Shuttle fleet; and, (3) the pursuit of **valve design improvements** including redesign of the pilot stage poppet surface area, changing the Teflon seal from a flat to a conical seal, and increased spring force on the pilot stage. These programmatic changes have been, or are being, implemented into the Shuttle fleet and are intended to provide a broad range and long-term solution to the concerns about RCS thruster leaks.

#### 3.4.5 *Mir* attitude for rendezvous and docking

In order to maintain adequate power margins, the *Mir* station must fly in an attitude to maximize solar panel exposure to the sun. The optimum attitude for collecting critical electrical power with the solar panels on the *Mir* is an inertial attitude. During Shuttle rendezvous and docking, the current procedures require the *Mir* to leave this inertial attitude, maneuver to and maintain an orbital attitude and maneuver the DM located on the Kristall module so that the docking port on the minus Z axis of the *Mir* is aligned toward the radius vector (towards the Earth). This procedure reduces *Mir* power reserves and can prevent a one revolution delay of the docking opportunity.

#### Resolution

Rendezvous and docking timelines have been modified to allow minimum time for the *Mir* to be out of its optimum solar collection attitude. The Shuttle is flown to a station keeping range of 170 feet (52 meters) before the *Mir* is maneuvered to docking attitude. Once the *Mir* has maneuvered to attitude, the time for the Shuttle to effect docking has been reduced to 25 minutes. If the Shuttle were to fly an approach and dock with the *Mir* in an inertial attitude, the

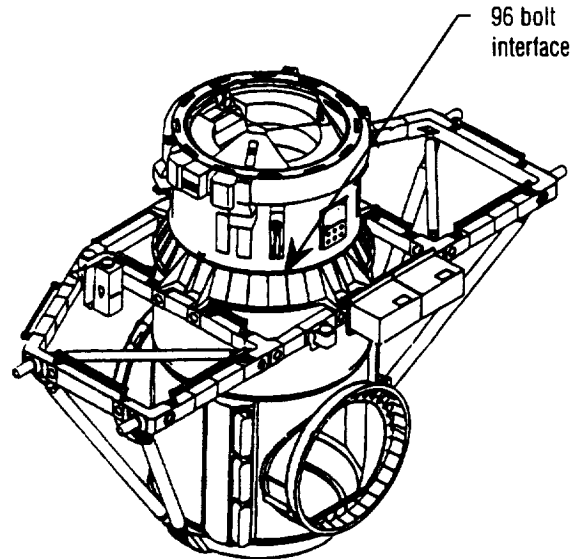
result would probably be significantly increased RCS activity with associated loads and plume contamination considerations. Consideration of this technique would require analysis of the anticipated docking loads, plume loads, propellant usage, and training.

### **3.4.6 Pyro-bolts failure contingency separation from Mir**

If the primary DM electro-mechanical hook activation and the back-up pyro-bolt activation fails during the Shuttle undock from the *Mir*, the proposed procedure was to perform an EVA from the Shuttle to remove the 96 bolts on the Orbiter Docking System (ODS) and separate at that interface (Figure 6). This procedure would leave the ODS cone attached to the Kristall module and render this docking port on the *Mir* station unusable.

#### **Resolution**

A proposal was made to activate the docking hooks on the Kristall side of the DM interface, leaving the DM attached to the Shuttle at separation. After separation and fly-away, the 96-bolt EVA would then be performed and the DM jettisoned, leaving the Kristall port accessible for



*Figure 6 — ODS showing 96 bolt EVA interface location. See figure 12 for ODS location in payload bay.*

further docking operations. This option was pursued and analyzed in order to maintain use of the Kristall docking port. The U.S. and Russian teams decided not to use this option in order to preserve a possible subsequent repair of the failed mechanical hooks and continued use of the DM by the Shuttle for continued logistic flights.

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## **3.5 MANAGEMENT**

### **3.5.1 Inadequacy of RSA bio-medical management structure**

Bio-medical support in providing safety and efficiency of the crew is a very important element in joint operations. Unfortunately, two different bio-medical structures were developed in the U.S. and Russia. Unlike the bio-medical structure at NASA, there is no bio-medical structure division in RSA. These functions are currently performed by the Institute for Biomedical Problems (IBMP).

#### **Resolution**

The Advisory Expert Council recommends that the RSA establish a chief position with responsibility and authority for medical operations. It is expected that the establishment of such a structure will provide adequate bio-medical

structures and will help to simplify the agreement and implementation of the joint bio-medical efforts.

### **3.5.2 Insufficient coordination between Working Group 8 and the TIMs**

Crew technical and medical support issues are not being well coordinated among the Working Group 8 and the Technical Interchange Meeting (TIM) groups.<sup>14</sup>

#### **Resolution**

For effective coordination of crew, technical and medical support issues, it is necessary to provide for regular attendance in the TIMs by Russian working group specialists, particularly regarding the authority of medical provisions of the crew. It would be prudent to have Russian specialists from Working Group 8 participate in the TIM.

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14. See attachment 9 for a list of the Phase 1 Joint Working Groups.



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# 4

## Completed Phase 1 Missions

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### 4.1

#### STS-60 MISSION

The Shuttle *Discovery* (STS-60) launched exactly on time at the beginning of its launch window, on February 3, 1994. Although the primary objectives of this flight were unrelated to the Phase 1 Program, the flight of cosmonaut Sergei Krikalev on STS-60 marked the resumption of U.S.-Russian joint activities in space. Krikalev, already a record holding cosmonaut in Russia, became the first Russian to fly on the U.S. Space Shuttle.

The Shuttle contacted the *Mir* via a "Good Morning America" live tri-directional audio and video down-link on February 8. The Shuttle landed on February 11 at KSC, ending an eight day mission.

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### 4.2

#### STS-63/MIR-17 RENDEZVOUS MISSION

On February 3, 1995, STS-63 (*Discovery*) launched from KSC. The primary objective of this mission was to perform a rendezvous with and fly-around of the *Mir* in order to verify flight techniques, communications and navigation aid sensor interfaces, and engineering analyses associated with Shuttle-Mir proximity operations in preparation for the STS-71 docking mission with the *Mir*.

The mission successfully accomplished a rendezvous to within 33 feet (10 meters) and fly-around of the Russian *Mir* Space Station at a distance of 396 feet (121 meters). The Shuttle crew evaluated the visibility of the docking target in various lighting conditions during the closest approach and visually assessed the condition of the *Mir* during the fly-around. The docking target was delivered to the *Mir* on a Progress in the spring of 1993 and installed via inter-vehicular activity (IVA) on the docking port hatch while the Soyuz was docked to the *Mir* Kristall port.

All flight operations were completed according to schedule, despite an RCS failure on *Discovery*. The Shuttle reached the closest allowable rendezvous point within several seconds of the planned time (allowable tolerance was plus or minus two minutes) and it maintained this position for ten minutes. The Terminal Control System (TCS) and Hand Held LASER (HHL) were successfully tested. Conferences for senior flight operation managers took place according to schedule.

The Shuttle landed at KSC on February 11, at 5:51 a.m., after 129 orbits of the Earth.

#### 4.2.1 Leaks from the Shuttle RCS thrusters

There were two RCS thruster problems during the launch of STS-63 and a third that occurred during flight. Thruster L2D failed and RCS R1U experienced a minor thruster leak during ascent. Thruster R1U was leaking at a rate of 2 to 3

pounds (0.9 to 1.4 kilograms) per hour when Commander James Wetherbee performed a 39 second Orbital Maneuver System (OMS) burn to place the Shuttle on an intercept course with the *Mir*. In addition, forward thruster F1F began leaking 3 to 5 pounds (1.4 to 2.3 kilograms) per hour during an RCS firing test on February 4.

Flight rules for the mission dictated that Discovery must have all aft firing thrusters operational before it moves to within 1,000 feet (305 meters) of the *Mir*. In past missions, leaks frequently stopped once the RCS jets were warmed by either thruster firings or the sun. Consequently, flight controllers directed Commander Wetherbee to position the orbiter so that the sun could warm up the leaking jet. The thrusters were cleared several times after pressure was allowed to build up in the manifold. After joint discussions and planning, Shuttle and *Mir* flight controllers agreed that the orbiter could approach to no closer than 33 feet (10 meters) from the *Mir*, as long as the right RCS Manifold #1 which provides fuel to the leaking R1U thruster was closed and the orbiter back off to 400 feet (122 meters) in the event of any loss of "Low-Z" RCS thruster capability.

It should be noted that, although the RCS leaks did not have a significant impact on this mission, there could have been Shuttle pollution which would have adversely affected the *Mir* station (see section 3.4.4).

#### **4.2.2 Loss of Low-Z redundancy**

Another issue surrounding the RCS jet leak was the potential for loss of other jets connected to the same manifold. In fact, the failure of any of the four Low-Z jets on the aft pods would leave the Shuttle without redundancy in Low-Z mode. If the STS-63 rules were applied to STS-71, loss of a single jet could mean loss of the joint mission. An alternative plan has been developed to provide

greater assurance of a successful docking and mated mission without compromising *Mir* structural loads margins. This consists of a technique for continuing the approach after closing the manifold which supplies the leaking jet. This plan has been documented in the flight rules and in the flight procedures for post STS-63 missions.

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### **4.3 MIR-18**

The historic *Mir*-18 mission began on March 14, 1995, with the launch of Soyuz TM-21. On board the Soyuz TM-21 were the crew commander, Vladimir Dezhurov, the flight engineer, Gennady Strekalov, and the first U.S. astronaut to launch on a Russian vehicle, cosmonaut-researcher Dr. Norman Thagard.

#### **4.3.1 Mir-18 objectives**

The primary objective of the *Mir*-18 mission was to prepare *Mir* systems and equipment in order to support the first docking of U.S. and Russian spacecraft since the Apollo-Soyuz Test Project mission of July 1975. In addition to performing docked operations with the Space Shuttle *Atlantis* (STS-71), the *Mir*-18 crew was tasked to conduct U.S. and joint U.S.-Russian scientific research, perform Russian scientific research and experiments, prepare *Mir*'s systems and equipment for the receipt of the Spektr module, and support *Mir* operations.

#### **4.3.2 Scientific research on Mir-18**

The *Mir*-18 mission is distinguished by the joint scientific accomplishments of its U.S.-Russian crew. This cooperative effort began an important series of cosmonaut-researcher exchanges on the



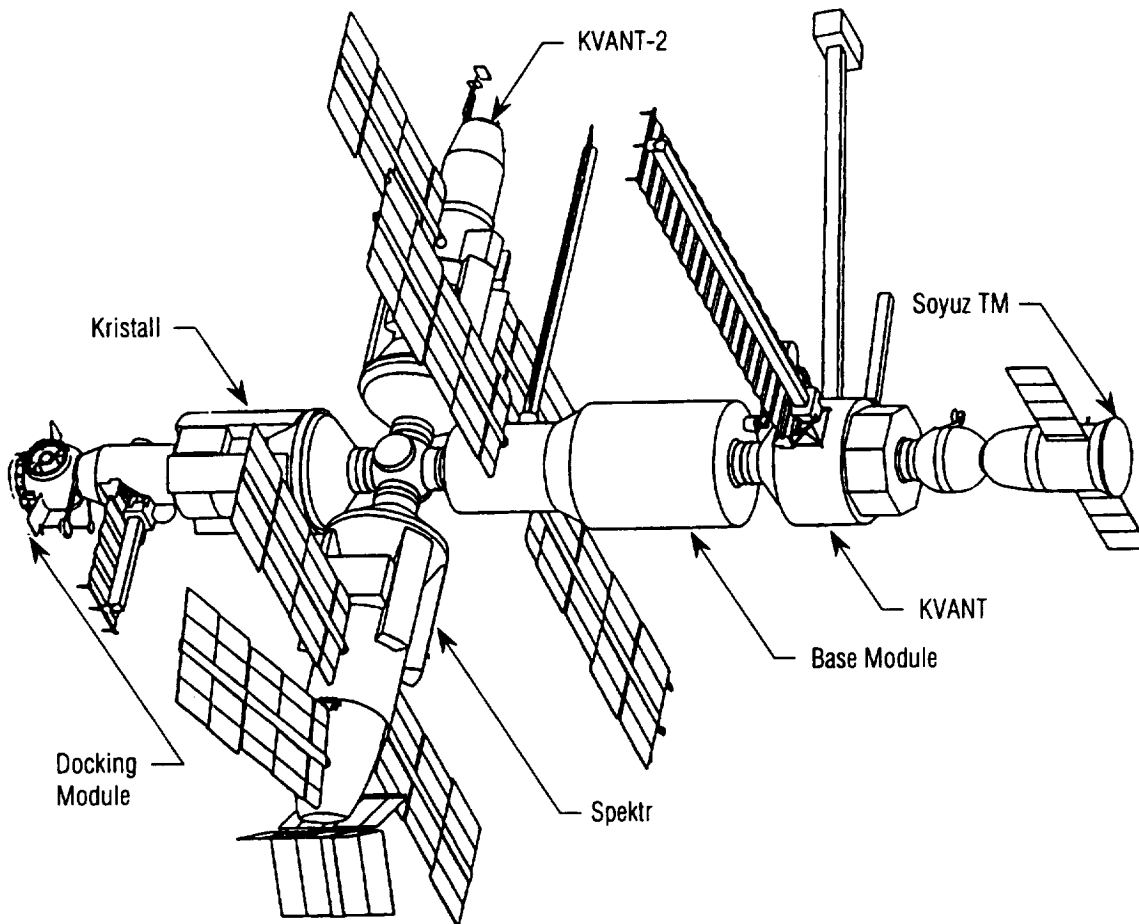


Figure 7 — Mir-18

Shuttle and on the *Mir* as part of the preparations for the construction of the ISS.

The scientific experiments (most of them medical) could be divided into six categories: (1) metabolic research; (2) cardiovascular research; (3) neuromuscular and neuro-sensor research; (4) hygiene research; (5) radioactive safety; and, (6) psycho-physical research.

During the *Mir-18* flight, 205 out of the 227 scheduled experiments were completed. The rest were postponed due to delays in the launch of science equipment on the *Spektr* module. A further impact to the joint science mission occurred when the crew had to perform two

additional EVAs at the expense of experiment time. As a result of these interruptions, some experiments were postponed to the next *Mir-19* mission.

#### 4.3.3 Experience of the U.S. Cosmonaut-researcher on *Mir-18*

Dr. Thagard integrated well into the *Mir-18* crew in both language capability and crew compatibility. As a result, he was able to perform and conduct valuable science on board *Mir*. In addition, Dr. Thagard's experiences highlighted the cultural and philosophical differences between

the U.S. and the Russian human space flight programs. In his post-flight review of his *Mir* experience, Dr. Thagard's comments included a desire for hot water (for both food preparation and hygiene), improved bathing facilities, food menus that reflected his individual taste preferences, additional opportunities to speak with MCC-H, and additional opportunities for personal communication with family members.

Each of Dr. Thagard's issues were addressed in support of the STS-76/NASA-2 mission. The details of these changes and the STS-76/NASA-2 mission are discussed in section 5.2.

#### **4.3.4 Activities in support of *Mir*'s operation**

After arrival of the *Mir*-18 crew aboard Soyuz TM-21 on March 17, 1995, the Soyuz TM-20 undocked from the *Mir* with the *Mir*-17 crew on March 22, 1995. The Progress M-27 successfully launched on April 9, 1995, and docked with the *Mir*. The Spektr module was inserted into orbit on May 20, 1995. With the Spektr launch, re-supply operations were resumed at the end of May, 1995. On June 1, 1995, Spektr docked with *Mir* and became the fourth module attached to the *Mir* structure.

In order to prepare for the Spektr docking, the Kristall module was moved from the minus Y axis to the minus X axis in three separate maneuvers between May 26 and June 10, coming to rest on the minus X axis of the main docking node on June 10, 1995.

#### **4.3.5 EVA Activities in preparation for the Spektr-*Mir* docking**

Five EVAs were performed by the *Mir*-18 Russian crew during their flight. Dr. Thagard performed the Inter-Vehicular crew support duties. The first EVA took place on May 12, 1995. Its objective was to perform preliminary operations required

for transportation of *Mir* Solar Array-2 (MSA-2) from the Kristall module to the Kvant module. A test folding of several panels of one of the arrays was completed on Kristall based on the commands issued by Dr. Thagard from the *Mir* control panel. Upon the completion of the test, the cosmonauts returned to the Station. This EVA lasted 6 hours, 15 minutes.

The second EVA was performed on May 17, 1995, by Dezurov and Strekalov. Their objective was to transfer the MSA-2 from Kristall to Kvant. Based on the commands issued by Dr. Thagard, a complete panel folding was implemented. The *Mir* Commander and Flight Engineer disassembled the MSA-2 and moved it to the Kvant module with the help of the Strela boom. The EVA lasted 6 hours, 54 minutes.

The third EVA was performed on May 22, 1995. Its objective was to install MSA-2 on the Kvant electric drive and connect it to the main power supply. EVA number three lasted 5 hours, 15 minutes.

The fourth EVA was performed on May 29, 1995. Its objective was to perform preliminary operations to reinstall a portable docking cone from the minus Y axis docking node to the minus X axis docking node and a seal from the minus Z to the minus Y docking node in order to prepare the Kristall module for redocking. This EVA lasted 21 minutes.

The fifth EVA was performed on June 2, 1995. Its objective was to install a portable docking device on the lateral node of the main docking node and redock the Spektr module to it. This final EVA lasted 24 minutes.

#### **4.3.6 Russian science performed on *Mir*-18**

The Russian scientific research in different fields was conducted automatically with the help of various equipment, such as ERE, SMMK, Ryabina,

## Completed Phase 1 Missions

Rentgen, Maria-2, Buket, and REM. A total of 450 separate experiments were conducted.

The data collected during experiments in the Shuttle-Mir program, as well as the scientific equipment was returned to Earth on STS-71.

### 4.3.7 Mir-18 anomalies

With outstanding support from the Mission Control Center in Moscow, the Mir-18 crew successfully addressed several anomalies which occurred during the mission. These anomalies occurred in the following areas: life support, power generation, docking seals and the Thermal Control System.

#### 4.3.7.1 LIFE SUPPORT

During crew ingress to Mir after the EVAs on June 17 and June 21, an anomaly occurred when a pressure equalization valve between the airlock and the core module could not be automatically opened. Ingress was possible through the use of the stationary and portable pressurization systems of the airlock section, which serve as the backup to the equalization valve. Analysis of the anomaly showed that the Station control system failed to relay the command to open the equalization valve. A software analysis is being performed on the Mir control system to determine the exact location of the failure.

#### 4.3.7.2 POWER GENERATION

Following its docking with the Mir, one of the Spektr solar array panels did not fully deploy (Figure 8). Errors in the Mir operations manual causing a disruption in the command sequence prevented one of the panels from being unlocked before deployment. STS-71 delivered both U.S. and Russian tools designed to free the panel, and the Russian crew performed successful EVAs to release and deploy the panels. The crew also performed EVAs in order to conduct

repairs and maintenance to the panels. Subsequently, four of the five solar array panel sections opened, followed by the fifth section some time later. The solar array is performing nominally at present.

Separately, an off-nominal temperature was noticed in the Kvant-2 storage batteries between June 20 and June 25. This was due to a failure of the battery compartment ventilation system to cool the batteries to an adequate level during multi-usage when the batteries were at full charge. Even though the temperature of the battery compartment made it difficult to address the problem, battery charging was verified and the possibility of partially reducing the charge of the batteries was examined.

#### 4.3.7.3 DOCKING SEALS

After redocking the Kristall module to the minus Z axis from the minus X axis in May, the crew encountered difficulties in pressurizing the docking node. They determined that the difficulty was due to a foreign object in the docking seal area.

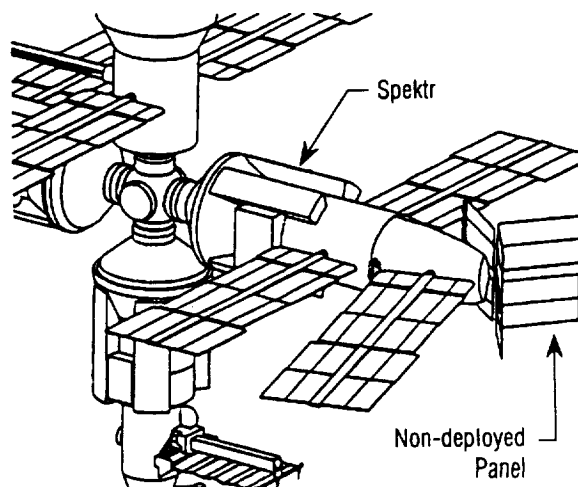


Figure 8 — Spektr solar panel deployment malfunction.

The pressure was restored after returning the Kristall module to the minus X axis.

#### **4.3.7.4 THERMAL ANOMALY**

Insufficient moisture collection, pressure oscillation in the heat transfer loop, and a failure in the fan switch were symptoms of a failure of the Water Conditioning Unit (WCU) to function properly during the *Mir-18* mission. While the failures caused a decrease in the quality of the air control system, no danger was posed to the life or health of the crew.

Several steps were taken by the MCC-M and the crew to respond to the WCU failure. New air channels now change the air flow. Thermal insulation of the WCU elements has been added preventing moisture from gathering on the connector which was causing incorrect thermostat readings. Thermal insulation of the WCU elements has been improved. Switcher failures have been reduced as a result.

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## **4.4**

### **STS-71/MIR-18 RENDEZVOUS AND DOCKING MISSION**

After being twice delayed by weather, the Space Shuttle *Atlantis* (STS-71) launched on June 27, 1995, conducting a "picture perfect" rendezvous and docking on June 29, 1995, the first of the Shuttle-Mir program. In addition to carrying Mir logistics, science experiments and five U.S. astronauts, STS-71 carried the Russian crew for the *Mir-19* mission: Anatoly Soloviev, crew commander, and Nikolai Budarin, flight engineer.

While the STS-71/*Mir-18* mission was politically important for the Phase 1 Program, it was also important for what it accomplished technically. During the STS-71/*Mir-18* joint operations, the U.S. and Russian crews: (1) successfully assembled in

space two large scale structures weighing more than 220 tons (200,000 kilograms); (2) smoothly coordinated with mission control centers in both Houston and Moscow; and (3) exchanged crews on each other's spacecraft.

The five full days of joint operations were conducted without major incident except for an anomaly that occurred after the Soyuz had undocked from the *Mir* in order to photograph the Shuttle separating from the *Mir* vehicle (see section 3.1.3). After the photography exercise was complete, *Atlantis* performed a fly-around of the *Mir* station prior to departure. The Shuttle landed safely at KSC on July 7 with the members of the *Mir-18* crew who had spent 115 days in space.

#### **4.4.1 Approach and docking loads**

Post flight analysis indicates all load and pressure indicators were well within constraints. Overall, loads were relatively benign, with the most significant response occurring at the Kristall-to-core module interface where tensile loading reached approximately 85% of the design limit.

#### **4.4.2 Transfers**

After launching aboard STS-71, the two Russian *Mir-19* crew members, Anatoly Soloviev and Nikolai Budarin, transferred into *Mir*. Approximately 200 items were also transferred to the *Mir*. It was found that item transfers should be scheduled logistically and not necessarily in priority order; for example, the re-supply items should be transferred to the *Mir* prior to transferring and stowing the return items as the Shuttle has limited storage space. It was also found that during the mission all control center inputs concerning transfer items should be coordinated via a single communication path through the MCC-M Deputy Mission Director (PRP) and the Russian Integration Officer (RIO).

Completed Phase 1 Missions

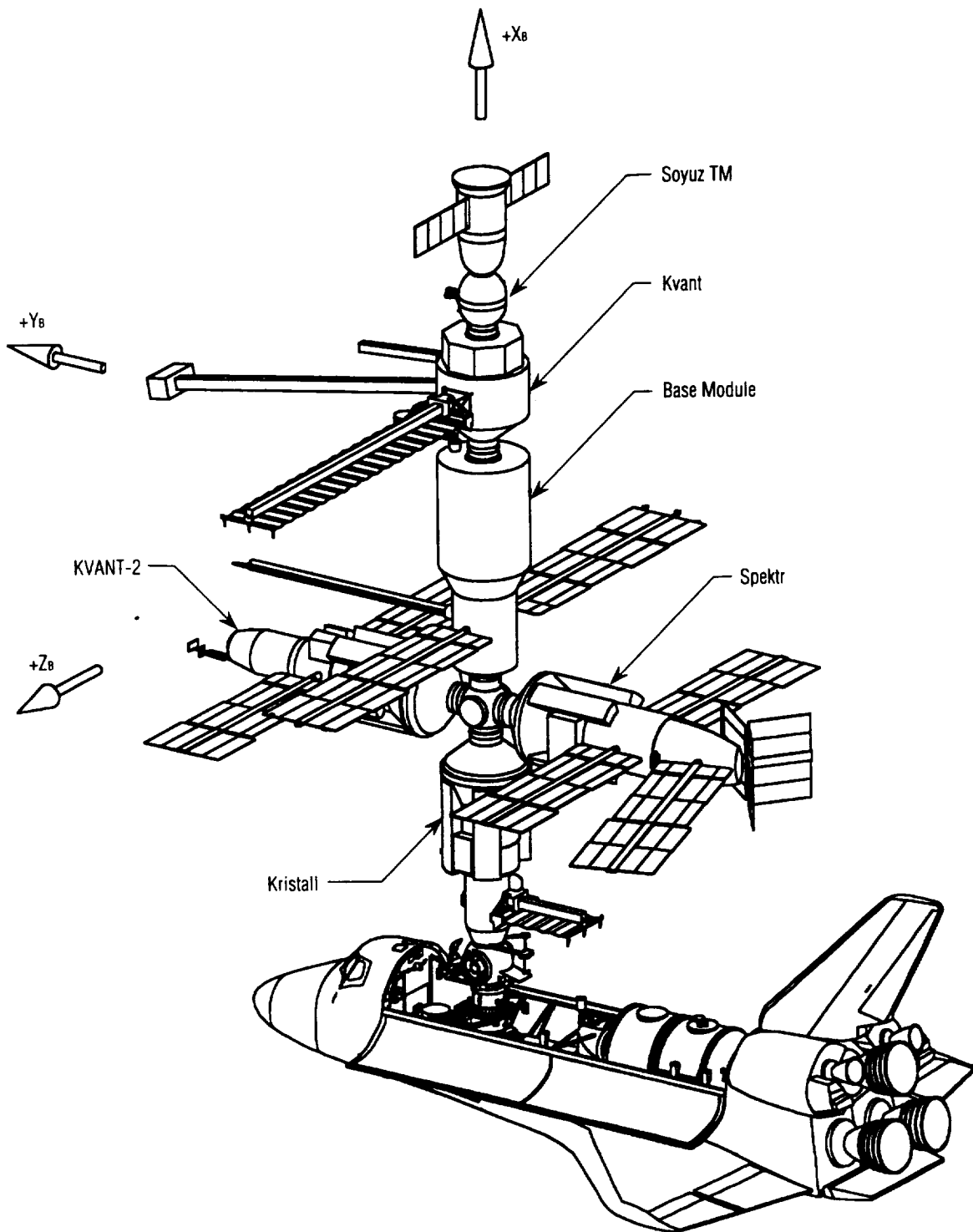


Figure 9 — STS-71/Mir-18 mated configuration.

#### **4.4.3 Atmosphere exchange**

The Shuttle provided adequate oxygen partial and total pressure and humidity control for the combined volumes while docked. This approach allowed unnecessary *Mir* systems to be deactivated to save electrical power.

#### **4.4.4 Communications**

Two measures were utilized to prevent harmful Ku-band radiation during this flight. Within 305 feet (93 meters) of the *Mir* or when docked with the Station, the Shuttle Ku-band system only operated at medium or low power and a radiation mask was used during all docked operations to preclude irradiating the *Mir* (see section 3.1.1).

Not all voice communication configurations were fully investigated prior to the STS-71 mission and some options were developed during the mission. These configurations may become the basis of communications for future Shuttle-Mir missions.

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### **4.5 MIR-19**

The flight duration of the *Mir-19* was 76 days total. The *Mir-19* crew returned to Earth on September 11, 1995, aboard the Soyuz TM-21.

In addition to successfully concluding the first Shuttle-Mir docking, the *Mir-19* mission executed several experiments from the Russian science program on *Mir*, completed maintenance operations on *Mir* and implemented an international cooperative program between Russia and the European Space Agency (ESA).

Materials results from completed Russian science program experiments, as well as part of the materials on the Shuttle-Mir joint science program, were returned to Earth on Soyuz TM-21.

#### **4.5.1 Mir systems failure**

On July 4, 1995, Soyuz TM-21 and Shuttle *Atlantis* undocking procedures were accomplished with no anomalies. The Soyuz undocked from the *Mir*, moved away, and took photographs of the Shuttle *Atlantis* undocking from the *Mir*. *Mir-19* Commander Soloviev and Flight Engineer Budarin then commenced redocking procedures for the Soyuz TM-21. At that time, a failure in the *Mir* attitude control system occurred. The *Mir* attitude control system was switched off and the Soyuz crew performed a manual docking to the *Mir* without incident. The crew later took actions to replace the failed systems, allowing the restoration of both the command and control system of the whole Station.

#### **4.5.2 Scientific experiments performed on Mir-19**

The *Mir-19* program included medical experiments not completed during the *Mir-18* mission because of the delay in the arrival of the Spektr module.

Additional solar panels on the Spektr module increased the power capacity of the *Mir* and allowed the accomplishment of technological and bio-medical experiments requiring high power during *Mir-19*, in addition to facilitating the completion of other experiments. At the same time, the work completed by *Mir-19* was somewhat reduced by the necessity of recovering from previously discovered malfunctions and incidents.

#### **4.5.3 Maintenance operations on Mir**

During its 76 day mission, the *Mir-19* crew completed three EVAs. The purpose of these EVAs was to conduct maintenance operations on

## Completed Phase 1 Missions

some Station structural elements. Scientific equipment was installed during the EVAs as well.

The first EVA was performed on July 14, 1995. Its purpose was to inspect Mir's external elements and complete necessary repairs. The crew examined the external surfaces of the Kvant-2, Kristall, and Spektr modules and evaluated the conditions of lateral docking nodes. Using equipment delivered to Mir by *Atlantis*, the crew cut off a defective safety latch on an additional Spektr Solar Array allowing it to open (see section 4.3.7.2). Time in space was 5 hours, 34 minutes.

The second EVA, performed on July 19, 1995, installed some Mir equipment and removed SKK-4, SKK-12, Trek, and Platan-N science equipment. During the opening of a hatch in the airlock, a malfunction in the space suit cooling system was detected, and Mr. Soloviev was ordered by MCC-M to stay near the exit hatch and direct the work of the flight engineer, Mr. Budarin. The flight engineer removed and retrieved a large detection device on the Kvant-2 surface. The detector had been used as part of the "Trek" experiment nearly four years for joint U.S.-Russian re-search on the generation of Galactic cosmic ray nuclei and their detection. The flight engineer removed cassettes with samples SKK-4, SKK-12 and the detector Platan-N structural materials from the external surface of the module and installed a two-panel Komplast in their places. Time spent in space was 3 hours, 8 minutes.

The objective of the third EVA on July 21, 1995, was an open valve on the Kvant-2 module connected to an additional vacuum line of the

"Electron" on-board unit. This valve is used in equipment which produces oxygen by water electrolysis. It was repaired in 5 hours, 50 minutes.

Also during the third EVA, a Belgian *Mirage* spectrometer was mounted onto a special truss constructed outside of the new unpressurized bay of the Spektr module, and was connected by cables to the on board power system.

### 4.5.4 Primary scientific results

The 477 scientific experiments in the fields of technology, bio-technology, applied sciences, geophysics, astrophysics, medicine, biology and mechanics

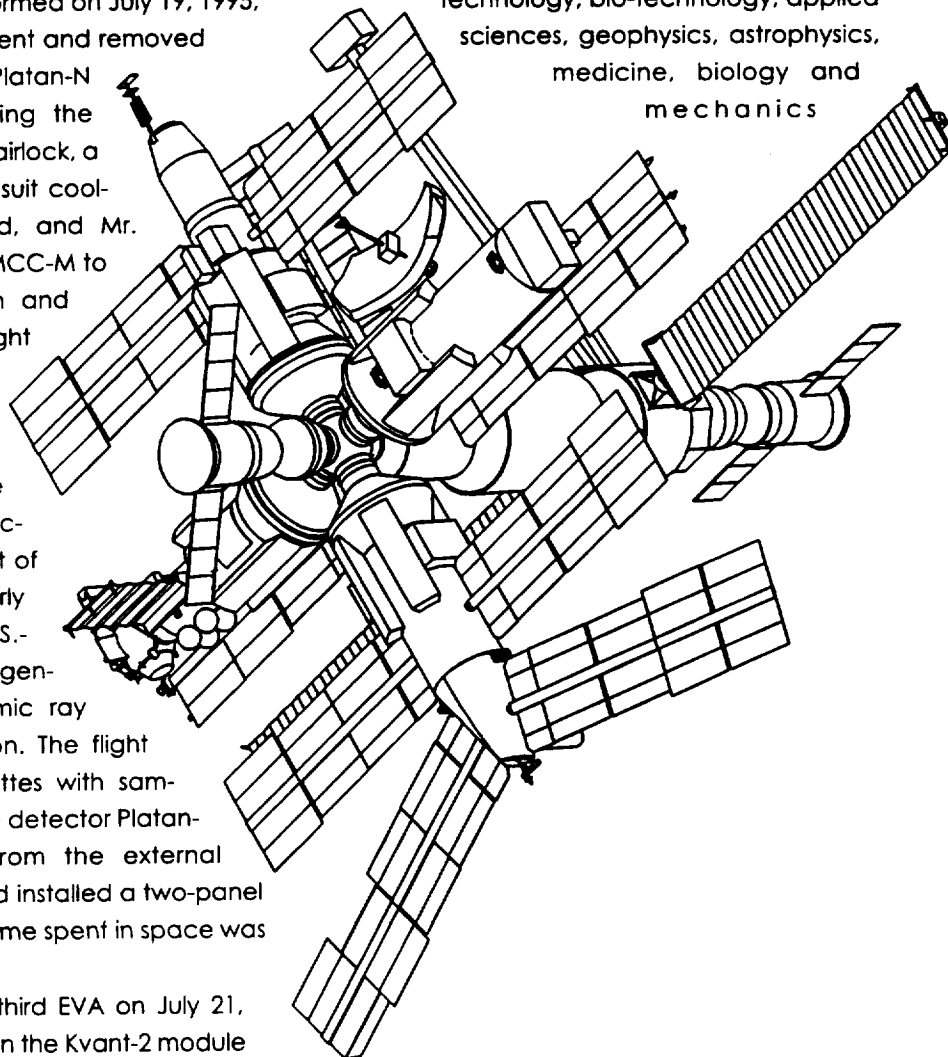


Figure 10 — Mir-19

were conducted and research was performed as part of the Shuttle-Mir program. Noteworthy results included the successful growth of a cadmium telluride mono-crystal with a diameter of 0.866 inches (2.2 centimeters) and height of 0.236 inches (0.6 centimeters), and the first stage of measurements using the Laser-Instrument Distance and Range (LIDAR) and Balkan-1 (a new generation of equipment for studying the Earth's atmosphere) instruments. Measurements of charged particles using a magnetic spectrometer, "Maria-2" were also made. These measurements enable researchers to register earthquake precursors and charged particles released due to solar flares.

The Mir-19 crew also performed crew medical examinations for crew health monitoring using onboard medical equipment made in Austria, performed technical experiments, and researched characteristics of the materials installed on Mir's external surface to evaluate the effect of external factors, such as Ultra Violet (UV) solar radiation, and atomic oxygen on the shield-vacuum insulation materials and their dielectric properties.

Finally, the Mir-19 crew performed the "Alpha-2" experiment to study the external atmosphere and effect of normal thruster exhaust on Mir. The experiment results provide a basis for mathematical models of the external atmosphere of Mir. Verification was not completed because the measurements were taken in only three locations near Mir's surface.

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## **4.6**

### **STS-74/MIR-20 RENDEZVOUS AND DOCKING MISSION**

On November 11, 1995, the Shuttle *Atlantis* (STS-74) launched from the Kennedy Space Center.

The mission successfully accomplished a rendezvous and docking with the Russian Mir Space Station on the Kristall module, located on the minus Z-axis of the main module. A 15.4 foot long DM to facilitate future Shuttle dockings was delivered and attached to the Mir with no incidents (Figure 11).

The reason for attaching the Russian-built DM, whose diameter is 7.2 feet (2.2 meters) and which weighs approximately 9,011 pounds (4,996 kilograms), was to reduce docking traffic on Mir's longitudinal axis port module while at the same time providing the Shuttle with its own docking port. Without the DM, Kristall would have to be moved to the longitudinal axis to provide clearance for each Shuttle docking. This location is undesirable for Kristall as normally this minus X port is used to dock Progress (M) and Soyuz (TM) spacecraft. In addition, it is not desirable to continually move the Kristall from port to port in preparation for a Shuttle docking because of the limitations on the usage of the *Kristall* manipulator arm.

#### **4.6.1 Consultant Group**

There are essentially two consultant groups, a Russian and an American group, that reside in

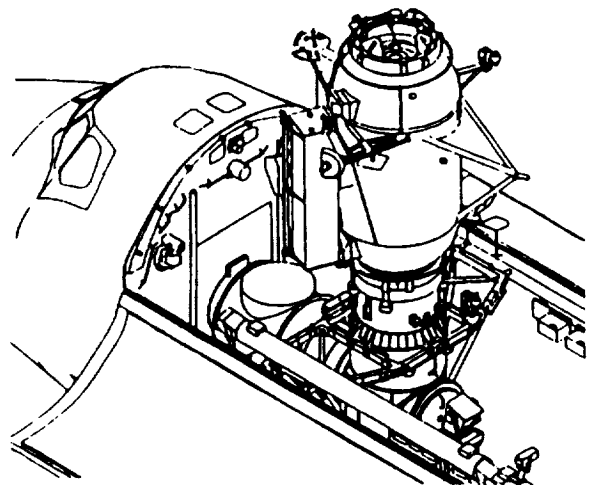


Figure 11 — Docking Module berthed on ODS.



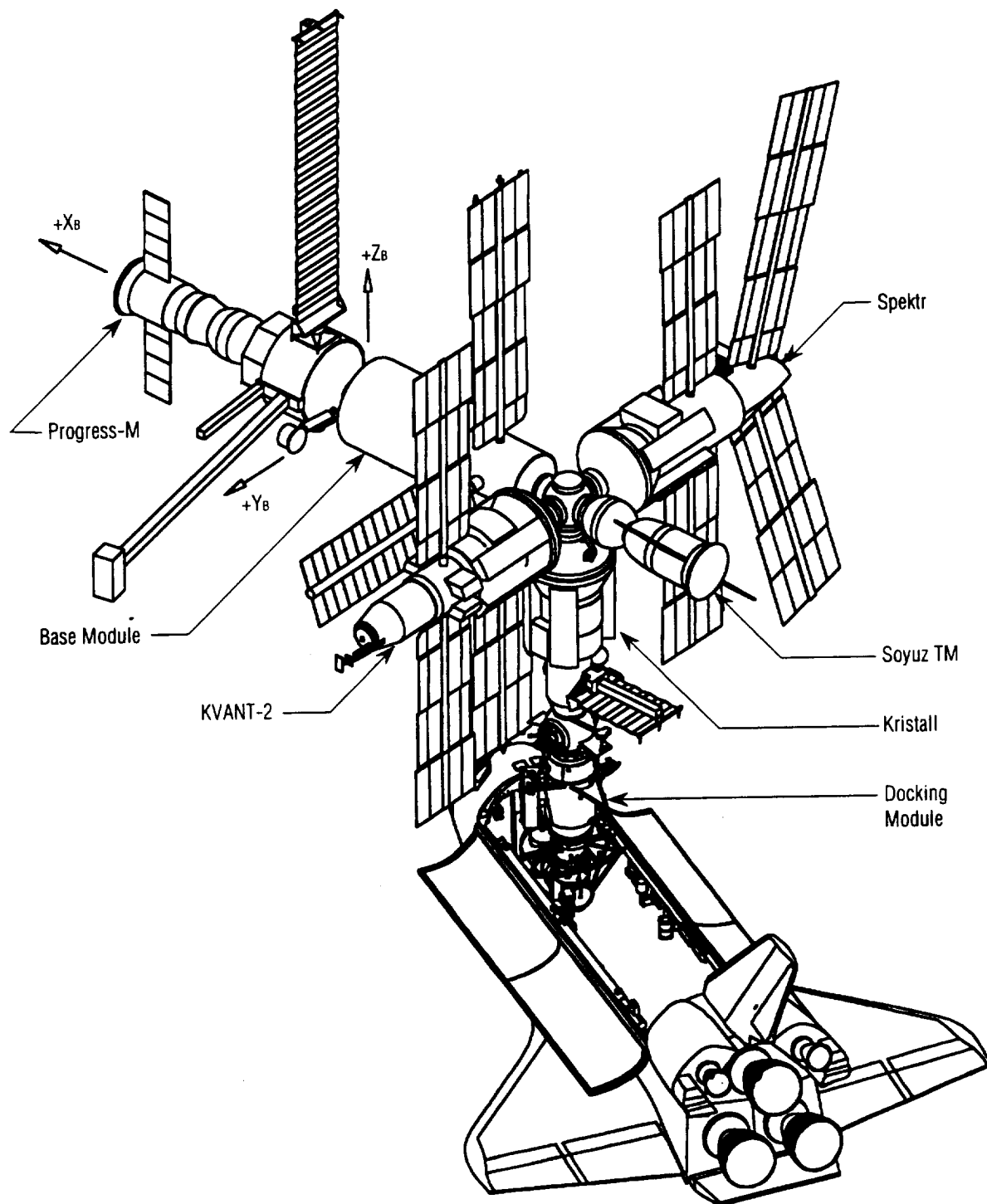


Figure 12 — STS-74/Mir-20 mated configuration.

MCC-H and MCC-M, respectively. These groups consist of a person from the Phase 1 program, a flight director, a systems expert, and a flight planning specialist that are available in the two control centers during Shuttle-Mir flights to confer with their counterparts on specific mission related problems. Using the consultant group as part of the planning process worked very well. There were joint consultations prior to up-linking to the *Mir* crew, which also worked well. Official transmission via the RIO and PRP ensured the proper processing of information by the MCC-H and MCC-M.

#### **4.6.2 Transfers**

STS-74 delivered scientific equipment, potable and distilled water, new clothing for the cosmonauts, and new solar arrays, to be stored on the DM until they could be transferred to the Kvant module. Transfer operations went well with no major changes to processes. The consultant group helped the coordination process.

#### **4.6.3 ISS Risk Mitigation Experiments**

The Risk Mitigation Experiments carried on-board STS-74 were completed successfully with the exception of the *Mir* Wireless Network Experiment (WNE).<sup>15</sup> The WNE is designed to demonstrate the operation of a radio frequency network of portable server computers, sub-notebook computers and personal digital assistants in a client/server and peer-to-peer distribution. This experiment was not operated on *Mir* because of Electro-Magnetic Interference (EMI) concerns. It was left on *Mir*, as suggested by the Russians, to be completed later. Additional certification tests were performed on WNE prior to the STS-76

launch. The test results enabled WNE operation on *Mir* during the STS-76/*Mir* 21 docked phase.

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### **4.7 MIR-20**

Together with Crew Commander Yuri Gidzenko and Flight Engineer Sergei Avdeev, ESA astronaut Tomas Reiter was launched on Soyuz TM-22 on September 3, 1995. During the 179 day *Mir*-20 mission, the crew conducted planned research and experiments, executed necessary repair or maintenance operations, and received cargo from the Progress M-29 on October 5, 1995, Shuttle STS-74 on November 14, 1995, and the Progress M-30 on December 17, 1995.

The *Mir*-20 mission program included allocating resources for priority experiments and research, consistent with agreements with NASA and ESA for the Shuttle-Mir and Euro-Mir-95 programs respectively.

#### **4.7.1 Scientific research on *Mir*-20**

In addition to WNE, research under the Shuttle-Mir program was conducted on noise level experiments and the parameters of electromagnetic fields on the Station.

As part of the Phase 1 Program, *Mir*-20 continued a wheat cultivation experiment which was initiated in the Svet hothouse by the *Mir*-19 crew.

#### **4.7.2 Joint Euro-Mir research**

In addition to conducting the scientific research, Tomas Reiter functioned as a crew member in operating the *Mir* Station.

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15. See Attachment 11 for a list of RMEs and the missions on which they will be performed.

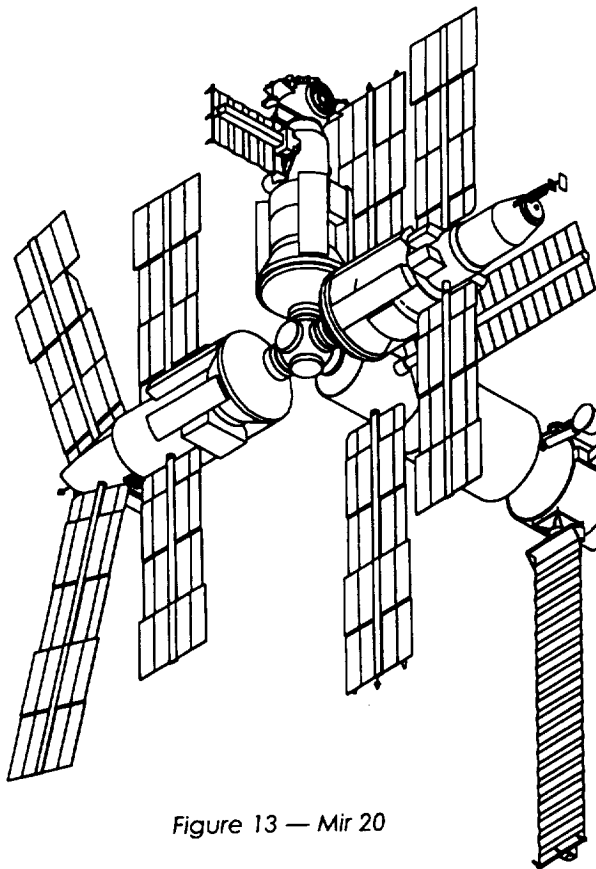


Figure 13 — Mir 20

#### Completed Phase 1 Missions

LIDAR equipment, and photo equipment delivered on the Spektr module.

During the Russian program part of the Mir-20 mission, 192 experiments were planned covering biological, geophysical, astrophysical, material and applied sciences, and technology. Overall, data from more than 300 geophysics, astrophysics, material sciences, applied sciences, and technology experiments was down linked. The experiments were operated with 37 equipment items, totaling a mass of approximately 7,606 pounds (3,457 kilograms).

There were more than 520 research experiments planned within the Euro-Mir-95 program. ESA equipment, delivered on Progress M-28, Progress M-29, and with the Mir-20 crew on the Soyuz TM-22 was used to conduct research on Mir. The total mass of Euro-Mir equipment was 1,096 pounds (498 kilograms).

Medical experiments in various disciplines are the primary focus in Euro-Mir-95. The program includes metabolism research, the effect of body position in weightlessness on the vestibular apparatus, bone tissue, respiratory and cardiovascular systems. Experiments were conducted on the study of radiation effects on humans during long-duration space flight, and the effect of radiation on the on-board electronics. Experiments in technology, in materials science, and in monitoring the Mir's environment were also performed.

#### 4.7.3 Russian scientific research

The Mir-20 crew conducted ecological and natural sciences experiments using spectrometry,

#### 4.7.4 Maintenance operations on Mir

In October, the flight engineer and second flight engineer of Mir-20 performed an EVA to install European scientific equipment, and replaced tapes in the Swedish-Russian interstellar gas detector. The second EVA occurred in December 1995 after the arrival of Progress M-30.

#### 4.7.5 Thermal Control System anomaly

On October 31, 1995, while continually observing the Mir flight, specialists of MCC-M noticed reduced pressure in the merge loop of the Thermal Control System in the core module, and in Kvant. Operational analysis of the on-board situation indicated that the coolant loop inside the module had lost pressure.

Experts recommended shutting off the coolant loop pump. System engineers appraised the leak at no more than 0.475 gallons (1.8 liters) of the coolant loop fluid (36.8% water solution of ethylene) into the compartment's atmosphere.

The *Mir* crew, with the participation of MCC-M experts, identified the location of the leak. A 0.472 inch (1.2 cm) crack at 45 degrees to the line axis was discovered in a bend in the coolant line at the KPR1 valve.

The crew performed the repair operation using two types of sealers and cloth bandages. Checking the loop under pressure showed no leak, and the telemetric pressure control, integrated with the loop, confirmed normal pressure in the loop. However, the thermal element was full of air gaps that were blocking the normal circulation in the loop. It was decided to build the new integrated loop by connecting to the back-up loop of the Kvant module. Normal parameters of temperature, pressure, and changes in pressure were obtained in the new integrated loop, confirming normal circulation of thermal elements in the loop.

As a result of the operation, the thermal element was deactivated. The IBMP examined the situation that had occurred, and recommended continuing the flight.

As a result of the repair work on board *Mir*, RSC "Energia" and the Salyut division of the Khrunichev Center recommended accepting integration of the newly created coolant loop to the Thermal Control System on *Mir*'s core and Kvant modules. They also recommended continuation of the *Mir*-20 mission without interruption including the scheduled STS-74 rendezvous and docking mission.

Refilling the deactivated loop of the thermal element was recommended during maintenance work on-board *Mir* in the first half of 1996. The results of future work will determine the necessity of refilling the deactivated loop again.

From the view point of known failures and the steps that were taken to eliminate them, the condition of the *Mir* allowed for execution of the planned scope of work for the *Mir*-20 program. However, in light of numerous gyrodrone failures

on the *Mir*, additional analysis on extending the Station's resources were required prior to the end of *Mir*-20 mission, scheduled for the end of February 1996.

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## **4.8**

### **STS-76/MIR-21 RENDEZVOUS AND DOCKING MISSION**

STS-76 launched on March 22, 1996, and docked with the *Mir* on March 23, 1996. In order to provide a more optimum attitude for *Mir* solar energy collection on this flight, the *Mir* was rotated 180 degrees in yaw. This required *Atlantis* commander Kevin Chilton to perform a corresponding 180 degree yaw maneuver during the final approach. This was the first time that this maneuver was performed, yet no safety or mission success issues were encountered. The operational knowledge and experience gained was valuable and will be applied to any future missions requiring the tail forward approach.

*Atlantis* delivered Dr. Shannon Lucid to *Mir* for a five month stay during which she will perform duties as member of *Mir*-21. During this time, Dr. Lucid will operate as *Mir* Flight Engineer-2 and NASA's second Cosmonaut-researcher. Subsequent U.S. astronauts will also work on *Mir* in this dual capacity. After five months on board *Mir*, Dr. Lucid will return to Earth on STS-79 in August 1996.

*Atlantis* carried a Spacehab single module in its payload bay, and remained docked to the Russian Station for five days. This was Spacehab's maiden voyage for a docking with *Mir*. While the Shuttle was docked to the *Mir*, astronauts Linda Godwin and Michael Clifford successfully performed a space-walk which transferred four experiments from *Atlantis*' payload bay to *Mir*'s exterior and evaluated hardware to be used on

Completed Phase 1 Missions

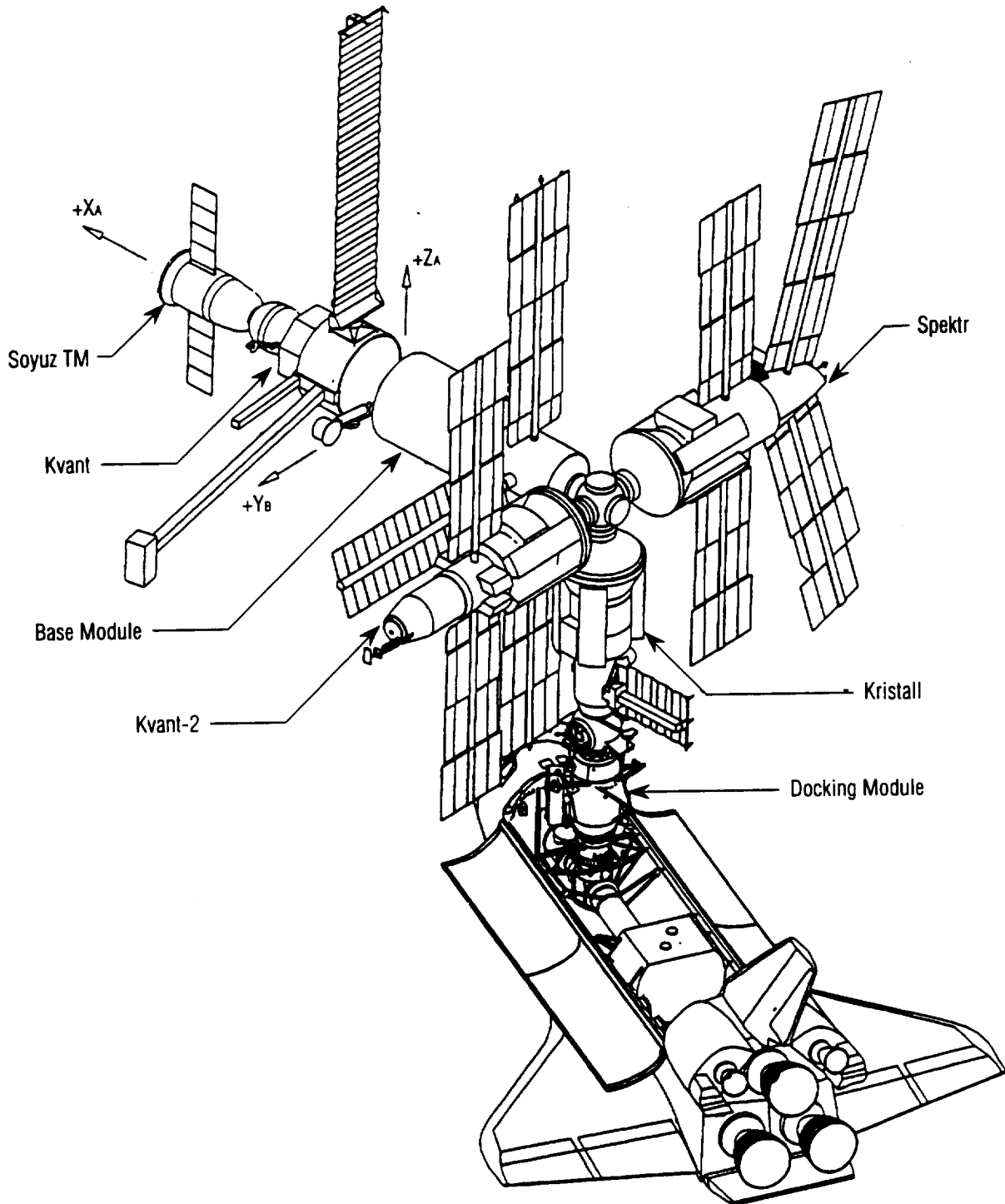


Figure 14 — STS-76/Mir-21 mated configuration.

## *First Joint Stafford-Utkin Report: Shuttle-Mir Rendezvous and Docking Missions*

the ISS. STS-76 was also the first operational use of the Simplified Aid for EVA Rescue (SAFER), the first self-rescue device for the ISS.

### **4.8.1 ISS Risk Mitigation Experiments**

During the Shuttle-Mir docked phase, several investigations were performed. These experiments measured Shuttle-Mir alignment and stability and characterized Mir's electric field. The Mir WNE that was to have been performed on STS-74/Mir-19, was performed during the STS-76/Mir-21 docked phase.

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# 5

## Current Phase 1 Mission

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### 5.1 MIR-21

The Soyuz TM-23 with the 21st Mir mission's Commander, Yuri Onufrienko, and Flight Engineer-1, Yuri Usachev, launched as planned on February 21, 1996. The duration of Mir-21 is 191 days. The third Shuttle-Mir docking occurred after Shuttle Atlantis (STS-76) launched on March 21, 1996. The Mir-21 crew also received Progress-31 and Progress-32 cargo transportation vehicles.

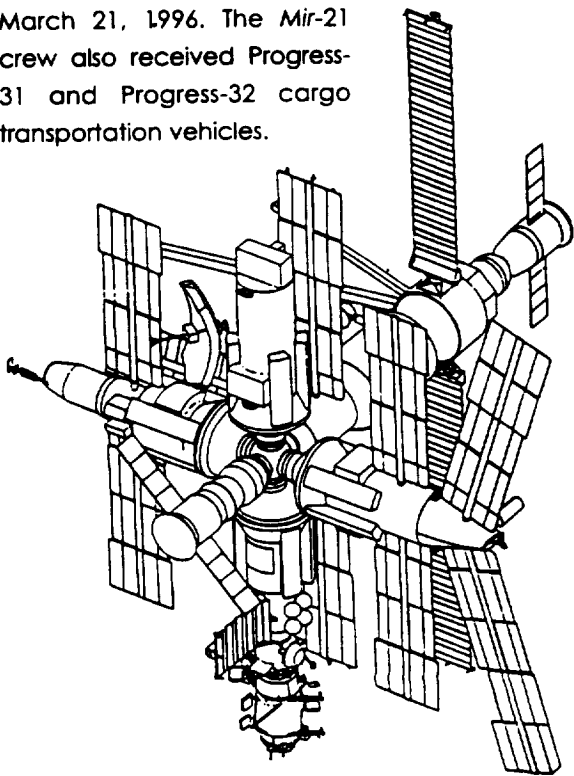


Figure 15 — Mir-21

During five days of joint operations, the crews from the U.S. Shuttle *Atlantis* and the Russian *Mir-21* transferred water and new equipment for experiments from *Atlantis* to *Mir*. These items were used to conduct research experiments on board the *Mir* Station. They also transferred from the *Mir* to *Atlantis* scientific research results for return to earth. The crews executed joint scientific experiments during one six hour EVA, where U.S. astronauts from the Shuttle installed an external payload on the DM. This payload is called the *Mir* Environmental Effects Payload (MEEP). The MEEP consists of four experiments: Passive Optical Sample Assembly I and II (POSA I/POSA II), Polished Plate Micro-meteoroid and Debris (PPMD), and the Orbiter Debris Collector (ODC).

In response to the lessons learned on *Mir-18*, NASA and RSA are providing Dr. Lucid with more video and audio news uplinks in English, more frequent conferencing with family members, more U.S. food, and more two-way audio and video opportunities than was provided for Dr. Thagard.

#### 5.1.1 Joint scientific research on *Mir-21*

The crew of *Mir-21* received the *Priroda* module on April 23, 1996, a one month delay from the baseline schedule. The *Priroda* module, weighing 45,415 pounds (20,643 kilograms), docked for six days to the main docking node of the core module, and then was re-docked to the side

docking node on the plus Z-axis. Scientific equipment weighing 2,063 pounds (938 kilograms) will be installed in the module. This includes equipment for use by the U.S. cosmonaut-researchers for their six missions aboard *Mir*, and Russian equipment for research, experiments for RSA, and ESA science equipment.

The joint science investigations include experiments in human life sciences, microgravity, fundamental biology, advanced technology, and earth science. Of the human life sciences experiments, focus will be on musculoskeletal performance and characteristics, crew to crew and ground to crew interactions, and the microbiological make-up of the *Mir* and crew. Several ISS risk mitigation experiments will be performed, including loads sensing and structural dynamics experiments.

### **5.1.2 Maintenance operations**

The *Mir*-21 crew is responsible for six EVAs: (1) mounting the cargo crane TC-4, docking of the power system (PGS) connectors and leveling the drive pins on the Kvant module on March 15, 1996; (2) transferring the Cooperative Solar Array (CSA) from the DM to the Kvant module and mounting it on the Kvant module on May 21, 1996; (3) deploying the mounted CSA on May 25, 1996; (4) mounting the MOMS-2P spectrometers, redocking the *Mirage* equipment in position I to 90°, and changing the node to conduct Komza experiment; (5) exchange of data tapes, installation of NASA MSRE and PIE scientific equipment, and installation of mountable tape for the SKK-11 container on June 6, 1996; and (6) assembling Tress-3, a large volume structure on June 13, 1996.



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# 6

## Future Phase 1 Missions

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### 6.1

#### **STS-79/Mir-21 Rendezvous and Docking Mission**

The beginning of NASA's 3rd mission aboard *Mir* is scheduled for August 3, 1996, with the launch of STS-79 on July 31. Colonel John Blaha, the third NASA cosmonaut-researcher, will transfer to the *Mir*, replacing Dr. Lucid, and will remain on board for 133 days. The duration of the joint STS-79 and *Mir*-21 mission (the fourth Shuttle-Mir rendezvous and docking mission) will be five days.

*Atlantis* will carry a Spacehab double module comprising of approximately 91 mid-deck transfer items.

In addition to rendezvous and docking with the *Mir*-21, and change-out of the U.S. cosmonaut-researcher crew, this Shuttle-Mir mission will execute joint science research, deliver scientific equipment for conducting research including ECLSS elements, and deliver Russian equipment and water to *Mir*. Scientific research and experiment data collected on *Mir*, and Russian equipment, will be returned to earth on STS-79.

The special significance of Colonel Blaha's flight aboard *Mir* is that it will give him a chance to work closely with not only four Russian colleagues from *Mir*-21 and *Mir*-22, but also the opportunity to work with one French cosmonaut-researcher.

#### **6.1.1 ISS Risk Mitigation Experiments**

While docked to the *Mir*, the STS-79 crew will perform several experiments to reduce risk on the ISS. These include continuation of a photo survey of micrometeoroid and debris damage to *Mir* structures (begun during the STS-63 mission), testing of an active rack isolation system, and use of a real-time radiation device. Shuttle-Mir alignment will also be measured.

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### 6.2 **MIR-22**

On August 14, 1996, the *Mir*-22 mission will launch on Soyuz TM-73 with two Russian cosmonauts, Commander Gennady Manakov and Flight Engineer-1 Pavel Vinogradov. Also on board the Soyuz TM-73 will be one French cosmonaut-researcher, Dr. Claudie Andre Deshayes, representing the Centre National d'Etudes Spatiales (CNES). The duration of the *Mir*-22 mission is 192 days. The duration of the French cosmonaut-researcher's visit on *Mir* will be 14 days.

During the fourteen day crew turnover period from August 16 to 30, six astronauts from three countries will work on board *Mir*: two members of *Mir*-21 mission the third U.S. cosmonaut-researcher, two Russian members of *Mir*-22 mission and the French cosmonaut-researcher. The Russian cosmonauts of the *Mir*-21 crew,

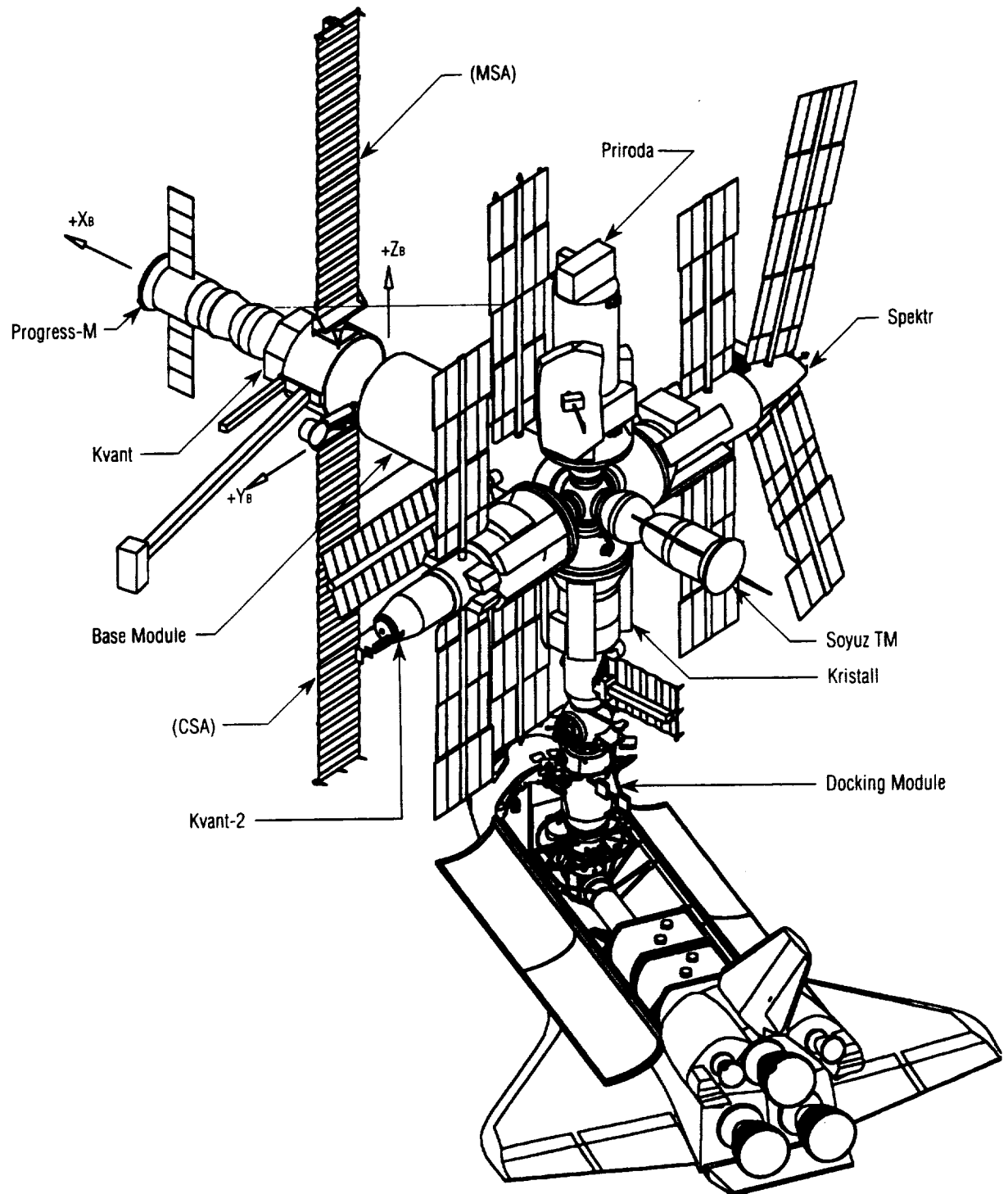


Figure 16 — STS-79/Mir-21 mated configuration

together with the French cosmonaut-researcher, will complete this joint phase of the *Mir-21* mission on August 30, 1996, and return to Earth via Soyuz TM-23, landing in Kazakhstan.

The third U.S. cosmonaut-researcher, delivered on STS-79, will join the Russian *Mir-22* crew and continue the joint Shuttle-Mir research on *Mir*. It is planned that the Progress M-33 cargo transport vehicle will dock with the *Mir* in September 1996.

### 6.2.1 Scientific research on *Mir-22*

The completion of the third U.S. cosmonaut-researcher's mission on the *Mir* station is planned for December 1996 with his return to Earth on "*Atlantis*" (STS-81).

During the 133 day *Mir-22* mission, the third U.S. cosmonaut-researcher will conduct several human life sciences experiments, including experiments designed to show the effects of long-duration space flight on human metabolism, neuro-sensory coordination and bone mineral loss and recovery. Medical monitoring will be conducted in addition to several experiments on *Mir* hygiene, sanitation and radiation. Microgravity, materials science, and biotechnology experiments will also be performed in addition to fundamental biology experiments. Several advanced technology and earth science experiments will be performed.

### 6.2.2 Maintenance operations

The following four EVAs are planned for the *Mir-22* Mission: (1) dismantling the PMSB-2 and MSA,

located on Kristall module; (2) folding and jettisoning the PMSB-4, located on the 4th plane of the Kvant module. Before being jettisoned, a section of PMSB-4 would be cut out to be returned to Earth for micro meteoroid damage analysis; (3) transferring the SAD from the DM and mounting it on the 4th plane of the Kvant module; and (4) deploying the SAD on the Kvant module. A decision on SAD mounting will be made based on the results of PMSB mounting. The *Mir-22* Mission Program is scheduled to receive two cargo transportation vehicles, "Progress-33" in September and "Progress-34" in December 1996.

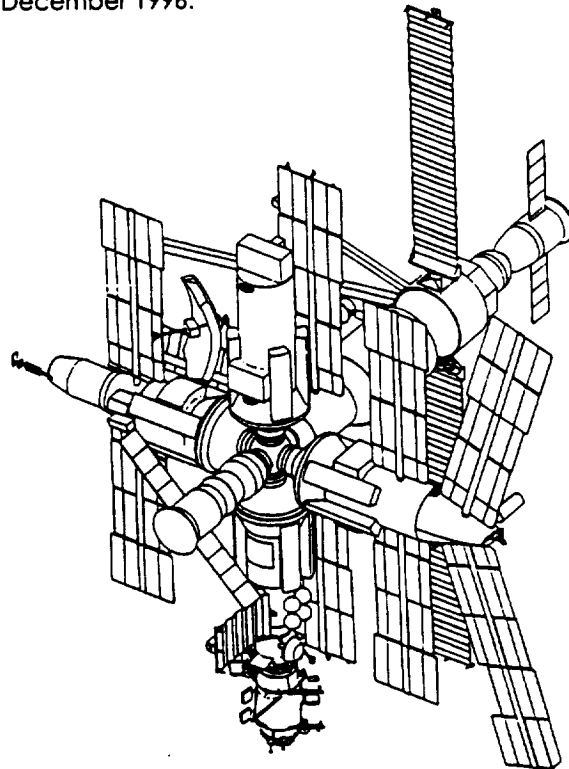


Figure 17 — *Mir-22*



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# ATTACHMENT 1

## Task Force on the Shuttle-Mir Rendezvous and Docking Missions

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### Chairman

**Lt. Gen. Thomas P. Stafford, USAF (Ret.)**  
Stafford, Burke and Hecker, Inc.

### Review Team Members

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Chief Operating Officer  
United Space Alliance

**Mr. Joseph Cuzzupoli**  
Senior Vice President  
American Pacific Corporation

**Dr. Charles C. Daniel**  
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**Dr. John Fabian**  
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**Dr. Craig L. Fischer**  
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**Dr. Michael A. Greenfield**  
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**Maj. Gen. Ralph Jacobson, USAF (Ret.)**  
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Special Assistant for Engineering,  
Operations and Safety  
Office of the Director  
NASA JSC

*First Joint Stafford-Utkin Report: Shuttle-Mir Rendezvous and Docking Missions*

**Executive Secretary**

Mr. Gilbert R. Kirkham  
Office of Space Flight  
NASA Headquarters

**Technical Advisors**

**Maj. Gen. Joe H. Engle, USAF (Ret.)**  
President  
Engle Technologies, Inc.

**Mr. Glynn Lunney**  
Vice President and Program Manager  
United Space Alliance

**Mr. Michael Weeks**  
Deputy Director, National Aerospace Plane  
Office of Aeronautics  
NASA Headquarters

**Ex Officio Member**

**Mr. James C. Snowden**  
Program Manager  
Johnson Engineering Corporation

---

# ATTACHMENT 2

## Membership of the Advisory Expert Council

---

### Representative

**Utkin, Vladimir Fedorovich**  
Academician  
Director, TsNII Mash

### Council Members

**Aleksandrov, Yuri Victorovich**  
Department Head, NPO AP

**Aliev, Valery Geldarovich**  
Deputy Head of Korolev RSC Energia  
Deputy Design General of the Korolev  
RSC Energia (from 12/22/95)

**Gazenko, Oleg Georgievich**  
Academician; IBMP  
President of the Russian Physiological Society

**Kovalenok, Vladimir Vasilievich**  
Major General, Air Force  
Superintendent, N. E. Zhukovsky Air Force  
Academy  
pilot-cosmonaut

**Lukyaschenko, Vasily Ivanovich**  
Deputy Director, TsNII Mash

### Executive Secretary of the Council

**Vasiliev, Leonid Petrovich**  
TsNII Mash

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# **ATTACHMENT 3**

## **NASA Advisory Council Task Force on the Shuttle-Mir Rendezvous and Docking Missions Terms of Reference**

**(Adopted May 1994)**

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### **A. BACKGROUND**

In October 1992, Russia and the United States formally agreed to conduct a fundamentally new program of human cooperation in space. This "Shuttle-Mir" Program involves combined astronaut-cosmonaut crew activities on the Shuttle, Soyuz, and Mir spacecraft. The first in this series was Shuttle mission STS-60 (February 3-11, 1994) which carried a Russian cosmonaut into orbit. In February 1995, STS-63 rendezvoused with Russia's Mir space station, also with a cosmonaut aboard. On March 14, 1995, a U.S. astronaut, Dr. Norman Thagard, and two fellow cosmonauts were transported via a Russian Soyuz booster and spacecraft to the Mir station where they will spend approximately three months. In May 1995, a joint U.S.-Russian crew, aboard STS-71, will rendezvous with the Mir station, dock, and perform cooperative science experiments; STS-71 will then return to the United States with Dr. Thagard and his two fellow crew members. Following STS-71, a number of additional rendezvous and docking missions with the Mir station will occur.

These missions will be technically complex undertakings, involving close cooperation between NASA and the Russian Space Agency.

New equipment, techniques, and procedures will need to be developed, and extensive training will be conducted. The margin for mission success can be enhanced if a team of experts is created to review all of these preparations on a periodic basis and report its findings and recommendations following each review session.

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### **B. SPECIFIC CHARTER AND REPORT- ING RELATIONS**

Within the context of the overall charter of the NASA Advisory Council (NAC) and its committees, the NAC Task Force on the Shuttle-Mir Rendezvous and Docking Missions shall:

1. Conduct periodic reviews of the preparations for the Shuttle-Mir missions through briefings and interviews as follows:
  - a. United States: NASA Headquarters, Lyndon B. Johnson Space Center, and other facilities as appropriate.
  - b. Russia and Commonwealth of Independent States: Space Station Liaison Office, Russian Space Agency headquarters, Mission Control Center - Moscow,



Baikonur launch facility, Gagarin Cosmonaut Training Center, and other facilities as appropriate.

2. Address the following areas and make appropriate recommendations:
  - a. Training
  - b. Operations
  - c. Rendezvous and docking
  - d. Management
3. Prepare interim reports following each review that detail the Task Force's findings and recommendations with a summary report to be produced prior to the missions and a post-mission report following their conclusion. These reports will be submitted to the Advisory Council.

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## **C. MEMBERSHIP**

The Task Force will be chaired by Lt. Gen. Thomas P. Stafford, USAF (Ret.). Members of the Task Force will be selected from experts in the various disciplines required for such a technical undertaking.

Technical and administrative support will be provided by the Office of Space Flight.

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## **D. DURATION**

The NAC Task Force on the Shuttle-Mir Rendezvous and Docking Missions is chartered for a period not to exceed two years unless terminated sooner or extended pursuant to the provisions of the Federal Advisory Committee Act.

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# **ATTACHMENT 4**

## **Advisory Expert Council Charter**

**PROVISION:**  
**Regarding the creation, status, tasks and organization of the Expert-Advisory Council's activities on problems relating to Shuttle-Mir flights**

**Council Representative**  
**Academician V. F. Utkin**

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### **1**

#### **BASIS FOR CREATION**

The Advisory Expert Council on Problems Relating to Shuttle-Mir Flights (AEC) was created by agreement at the Gore-Chernomyrdin Commission on 15 December 1994 and by the RSA decree, EO-21-74, from 12 January 1995. The General Director of the RSA approved the members of the Council.

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### **2**

#### **GOAL OF CREATING THE AEC**

The goal in creating the Advisory Expert Council (AEC) is to identify problematic issues, connected with the joint flights of the Space Shuttle and Mir, and to develop measures for increasing the level of reliability, safety and effectiveness of

the planned joint U.S.-Russian space flight program by a specially created collection of highly qualified experts, who are not directly involved in either the Shuttle-Mir or NASA-Mir programs.

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### **3**

#### **STATUS OF THE AEC**

The independent Advisory Expert Council (AEC), formed by the RSA, consists of the greatest scientific authorities and industry specialists who have been given the right to conduct verification during preparation, the degree of readiness and the identification of unsolved problematic issues in supporting the completion of the Shuttle-Mir and NASA-Mir programs within the framework of the first phase of the International Space Station Program.

Based on results of AEC's performance, RSA management would extend the Council's work to the next phase of the program.

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### **4**

#### **TASKS OF THE AEC**

**4.1** The continuation of the independent expert evaluations on the level of readiness of the technical means and support services for the completion of the planned program work, as well as

the level of safety, reliability and effectiveness of the joint Shuttle-Mir flights.

**4.2** The identification of existing defects and key issues, and analysis of their urgency.

**4.3** The evaluation of sufficient crew preparation to complete their functions and the coordination of means of their training for flight by the presented requirements.

**4.4** Development of recommendations, directed toward the removal of identified defects and increase of safety, reliability and the level of effectiveness in the impending work.

**4.5** Preparation and presentation to management of technical reports on the state of work with regards to the program.

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## **5 AUTHORITY OF THE AEC**

The Advisory Expert Council (AEC) acts within the framework of NASA-RSA agreements and is ensured of the following guaranteed possibilities:

1. Visits by the participants during the completion of the joint program and familiarization with the work being conducted.
2. Unlimited access to the technical-project and technical-operations documentation on the Mir and Shuttle facilities within the framework of the agreed joint program work.
3. The creation of working groups (WG) for the concrete problems of the Shuttle-Mir and NASA-Mir programs.
4. Attracting to the Council's work the leading specialists in the Shuttle-Mir and NASA-Mir programs.
5. Presence during the work-up of the most important steps of the flight, as well as during preparation as a whole.
6. Participation in the work of conferences and the solution of technical issues for the Shuttle-Mir and NASA-Mir programs.

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## **6 ORGANIZATION OF ACTIVITIES AND WORK PLAN**

**6.1** Academician V. F. Utkin is the Representative of the AEC.

**6.2** The members of the Council are chosen by the Representative and approved by the General Director of the RSA.

**6.3** The AEC's work takes place both in Russia and, by the consent of NASA, in the U.S.

**6.4** The AEC's work is conducted in coordination with the Schedule and Work Plan, by agreement of NASA and the RSA.

**6.5** The Work Plan can provide for visits of enterprise-developers and factory-manufacturers, mission control centers, cosmonaut training centers, entities of experimental ground bases and launch sites, scientific-research and other organizations involved in the Shuttle-Mir and NASA-Mir programs, as well as in the following measures:

- ☐ regular meetings of the AEC to summarize the results of the studies of the technical and

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programmatic documents, visits of the industrial organizations and entities, participation in the completion of the Shuttle-Mir and NASA-Mir programs and the drafting of corresponding recommendations;

- ❑ joint meetings of the AEC and NASA's Task Force for the Shuttle-Mir flights with approach and docking, headed by Lieutenant-General Thomas P. Stafford (USAF), to summarize and agree upon the plan of technical and organizational measures, in the areas of safety, reliability and effectiveness of completing the Shuttle-Mir and NASA-Mir programs;
- ❑ meetings of the Council and Task Force management and the leaders of the RSA and NASA to present, agree-upon and approve the results of the expert groups and to incorporate organizational and technical changes into the program.

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# ATTACHMENT 5

## Charter Shuttle-Mir Task Force and Advisory Expert Council

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### CHRONOLOGY

In May 1994, the Task Force on the Shuttle-Mir Rendezvous and Docking Missions was established by the NASA Advisory Council with Lt. Gen. Thomas P. Stafford, USAF (Ret.) as its chairman. The purpose of the Task Force is to review Phase 1 planning, training, operations rendezvous and docking and management. It provides interim reports containing specific recommendations to the Advisory Council and the NASA Administrator. To date, the Task Force has produced four independent reports.

Russian Prime Minister Chernomyrdin and U.S. Vice President Gore, at the December 15, 1994 meeting of the Gore-Chernomyrdin Commission (GCC), directed the General Director of the Russian Space Agency, Mr. Yuri Koptev, and the NASA Administrator, Mr. Daniel Goldin, to establish a process to review each other's program plans and capabilities and to report periodically to the GCC. In response to this direction, Mr. Koptev and Mr. Goldin agreed to form a joint committee. This committee, headed by Academician Vladimir Utkin, Director of the Central Institute for Machine Building (TsNII Mash), and Gen. Stafford, was charged to provide joint reports to the RSA General Director and the NASA Administrator.

General Director Koptev appointed Academician Utkin to chair the Advisory Expert Council on Mir station and Shuttle Vehicle Joint Flights Support Problems and formally approved its

membership on February 14, 1995. The Advisory Expert Council was instructed to provide independent assessments of the state of affairs, elaboration of recommendations, and additional measures, if necessary, of the level of reliability, safety, and efficiency of the planned program associated with the joint Russian-U. S. missions. The first independent report of this commission was produced on June 7, 1995.

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### CHARTER

Academician Utkin's Advisory Expert Council and Gen. Stafford's Task Force will jointly assess issues concerning the technical risks, risk mitigation plans and lessons learned from the rendezvous and docking missions. These assessments will result in at least two joint reports to be submitted to the General Director of the Russian Space Agency and the NASA Administrator: the first report assessing Mir 18-22, STS-63, STS-71, STS-74, STS-76 and STS-79; and the second assessing Mir 23-24 STS-81, STS-84 and STS-86.

In addition to their joint efforts, the independent work of the Advisory Expert Council and the Task Force will continue through Phase 1 with the participation in and the review of all aspects of the activity of their respective programs. Each will continue to produce independent separate reports containing necessary recommendations prior to each mission and, should the need arise,

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for emergent issues. The Advisory Expert Council will submit its independent reports and recommendations to the General Director of the Russian Space Agency. The Task Force will submit

its independent reports and recommendations to the NASA Administrator through the NASA Advisory Council.

*originally signed by:*

**Lt. General Thomas P. Stafford**

September 11, 1995

*originally signed by:*

**Academician Vladimir F. Utkin**

September 11, 1995

# ATTACHMENT 6

## Joint Report Development Timeline

	1995				1996				1997			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Mir			Mir 19 ▲	Mir 20 ▲	Mir 21 ▲	Mir 22 ▲	Mir 23 ▲	Mir 24 ▲				
Soyuz	▲ TM70		▲ TM71	▲ TM72	▲ TM73	▲ TM74		▲ TM75			▲ TM76	
Advisory Expert Council (AEC) Reports			▲ 8/95	▲ 12/95	▲ 6/96	▲ 10/96		▲ 4/97			▲ 10/97	
Joint AEC-Task Force Reports			▲ 10/95	.....	▲ 7/96	▲ 12/96	.....	▶				
Joint Meetings			▲ 9/8-12			▲ 11/11-15						
Task Force Reports to the NASA Advisory Council		▲ 6/95	▲ 10/95	▲ 3/96	▲ 7/96	▲ 11/96		▲ 4/97			▲ 9/97	
Shuttle		▲ STS-71	▲ STS-74	▲ STS-76	▲ STS-79	▲ STS-81		▲ STS-84			▲ STS-86	

# ATTACHMENT 7

## Bibliography

- ❑ *Implementing Agreement Between the National Aeronautics and Space Administration of the United States of America and the Russian Space Agency of the Russian Federation on Human Space Flight Cooperation*  
5 October 1992
- ❑ *Addendum to Program Implementation Plan*  
1 November 1993
- ❑ *Protocol to the Implementing Agreement between the National Aeronautics and Space Administration of the United States of America and the Russian Space Agency of the Russian Federation on Human Space Flight of October 5, 1992*  
16 December 1993
- ❑ *Contract NAS15-10110 between the National Aeronautics and Space Administration of the United States of America and the Russian Space Agency of the Russian Federation for Supplies and Services Relating to Mir-1 and the International Space Station: Phase One and Selected Phase Two Activities*  
23 June 1994
- ❑ *NASA-RSA Human Space Flight Cooperation Principles and Action Plan*  
26 January 1996
- ❑ *Fourth Report: Task Force on the Shuttle-Mir Rendezvous and Docking Missions*  
1 March 1995
- ❑ *The Advisory Expert Council's Report on the Problems Related to the Joint Mir-Shuttle STS-71 Flight*  
June 7, 1995



# ATTACHMENT 8

## List of Acronyms and Terminology

<b>ACES-LES</b>	<b>Advanced Crew Escape System/ Launch and Entry Suit</b>	<b>JSC</b>	Lyndon B. Johnson Space Center
<b>APDS</b>	Androgynous Peripheral Docking System	<b>KSC</b>	John F. Kennedy Space Center
<b>CNES</b>	Centre National d'Etudes Spatiales	<b>LES</b>	Launch and Entry Suits
<b>CoFR</b>	Certification of Flight Readiness	<b>LIDAR</b>	LASER-Instrument Distance and Range
<b>CITE</b>	Crew Integrated Test and Evaluation	<b>MCC-H</b>	Mission Control Center - Houston
<b>CSA</b>	Cooperative Solar Array	<b>MCC-M</b>	Mission Control Center - Moscow
<b>DM</b>	Docking Module	<b>MEEP</b>	Mir Environmental Effects Payload
<b>ECLSS</b>	Environmental Control and Life-Support System	<b>MS</b>	Mission Specialist
<b>EM</b>	Energy Module	<b>MSA2</b>	Module Structure Assembly 2
<b>EMI</b>	Electro Magnetic Interference	<b>MSRE</b>	Mir Sample Return Experiment
<b>ESA</b>	European Space Agency	<b>NAC</b>	NASA Advisory Council
<b>EVA</b>	Extravehicular Activity	<b>NASA</b>	National Aeronautics and Space Administration
<b>FDF</b>	Flight Data File	<b>ODC</b>	Orbiter Debris Collector
<b>FGB</b>	Functional Energy Block	<b>ODS</b>	Orbiter Docking System
<b>GCC</b>	Gore-Chernomyrdin Commission	<b>OMS</b>	Orbiter Maneuvering System
<b>GCTC</b>	Gagarin Cosmonaut Training Center	<b>PGS</b>	(Russian) Power System
<b>GNTc</b>	(Russian) State Scientific Center	<b>PIE</b>	Particles Influence Experiment
<b>HHL</b>	Hand Held LASER	<b>PMSB</b>	(Russian) Solar Array
<b>IBMP</b>	(Russian) Institute for Biomedical Problems	<b>POSAI/II</b>	Passive Optical Sample Assembly
<b>IR</b>	Infra-red	<b>POV</b>	Pilot Operated Valves
<b>ISS</b>	International Space Station	<b>PRCS</b>	Primary Reaction Control System
		<b>PRP</b>	(Russian) Deputy Mission Director
		<b>psi</b>	Pounds per square inch
		<b>R-bar</b>	Radius Vector
		<b>RCS</b>	Reaction Control System

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<b>REM</b>	Roentgen Equivalent Man (unit of dose equivalent)	<b>TM</b>	(Russian) Test Module
<b>RIO</b>	Russian Integration Officer	<b>TsNIIMash</b>	(Russian) Central Institute for Machine Building
<b>RSA</b>	Russian Space Agency		
<b>RSRM</b>	Reusable Solid Rocket Motors	<b>USAF</b>	United States Air Force
		<b>U.S.</b>	United States
<b>SAD</b>	(Russian) Cooperative Solar Array	<b>USSR</b>	(former) Union of Soviet Socialist Republics
<b>SAFR</b>	Simplified Aid for Rescue		
<b>SPIFEX</b>	Shuttle Plume Impingement Flight Experiment	<b>UV</b>	Ultra-Violet
<b>SRB</b>	Solid Rocket Booster	<b>V-bar</b>	Velocity Vector
<b>STS</b>	Space Transportation System		
<b>SSME</b>	Space Shuttle Main Engines	<b>WCU</b>	Water Conditioning Unit
		<b>WNE</b>	Wireless Network Experiment
<b>TCS</b>	Terminal Control System (Sensor)		
<b>TIM</b>	Technical Interchange Meeting		

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# ATTACHMENT 9

## List of Phase 1 Working Group

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<b>Working Group-0</b>	<b>Joint Management Working Group</b>
<b>Working Group-1</b>	Public Relations
<b>Working Group-2</b>	Safety Assurance
<b>Working Group-3</b>	Flight Operations/Integration
<b>Working Group-4</b>	Mission Science
<b>Working Group-5</b>	Crew Training and Exchange
<b>Working Group-6</b>	Mir Operations and Integration
<b>Working Group-7</b>	Extravehicular Activities (EVA)
<b>Working Group-8</b>	Medical Ops  Manifest and Schedule Sub-Working Group  Institutional Communications Working Sub-Group

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# ATTACHMENT 10

## List of Figures for the Joint Report

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<b>Figure 1</b>	NASA-Mir Program (Phase1) Launch Schedule (updated to 04/24/96).	<b>Figure 9</b>	STS-71/Mir-18 mated configuration.
<b>Figure 2</b>	ASTP and Shuttle-Mir docking mechanisms.	<b>Figure 10</b>	Mir-19.
<b>Figure 3</b>	Space Shuttle major components.	<b>Figure 11</b>	Docking Module berthed on Orbiter Docking System.
<b>Figure 4</b>	Braking maneuver showing Norm-Z and Low-Z modes.	<b>Figure 12</b>	STS-74/Mir-20 mated configuration.
<b>Figure 5</b>	V-bar and R-bar approaches.	<b>Figure 13</b>	Mir-20.
<b>Figure 6</b>	ODS showing 96 bolt EVA interface location.	<b>Figure 14</b>	STS-76/Mir-21 mated configuration.
<b>Figure 7</b>	Mir-18.	<b>Figure 15</b>	Mir-21.
<b>Figure 8</b>	Spektr solar panel deployment malfunction.	<b>Figure 16</b>	STS-79/Mir-21 mated configuration.
		<b>Figure 17</b>	Mir-22.

# ATTACHMENT 11

## ISS Phase 1 Risk Mitigation Experiments

Active Rack Isolation System  
 ADWIP (Autonomous Dynamics Wireless Instrumentation Package)  
 Audible Noise Measurement  
 CREAM (Cosmic Radiation Effects and Activation Monitor)  
 Crew Medical Restraint System  
 Enhanced Dynamic Load Sensors on *Mir*  
 ESA Proximity Operations Sensor  
 EVA In-Suit Doppler  
 GPS with Attitude Determination  
 Inventory Management System (bar code reader)  
 MEEP Return (*Mir* Environmental Effects Payload)  
 Microbiology Monitor  
 Micrometeoroid/Debris Photo Survey of *Mir*  
*Mir* Electric Field Characterization  
*Mir* Solar Array Evaluation Experiment  
*Mir* Structural Dynamics Experiments  
*Mir* Wireless Network Experiment  
 Optical Properties Monitor  
 Structural Dynamics Experiment)Passive

Optical Sample Assembly numbers one and two  
 Orbital Debris Collector  
 PASDE (Photogrammetric Appendage  
 Photo Appendage Dynamic Experiment  
 Polished Plate Micrometeoroid Debris  
 Radiation Monitoring Equipment III  
 Real-Time Radiation Monitoring Device  
 RME/EVA-1: Task Board  
 RME/EVA-2: Umbilical Demo  
 RME/EVA-3: Assembly and Maintenance  
 RME/EVA-6: Mass Handling  
 Shuttle-Mir Alignment Stability Experiment  
 Spacecraft External Contamination  
 SPSR (Spectroreflectometer)  
 Static Feed Water Electrolyzer  
 Trapped Ions in Space-2  
 Treadmill Vibration Isolation System Experiment  
 Vapor Compression Distillation System  
 Volatile Organics Analyzer  
 Volatile Removal System  
 Water Microbiological Monitoring  
 Water Quality Monitor

